Texas A&M Transportation Institute

Heavy-Duty Vehicle Idle Activity Study

Final Report

Prepared for

The Texas Commission on Environmental Quality

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Environment and Air Quality Division

TECHNICAL MEMORANDUM

PGA No: 582-17-74308-06

Activity Data Collection Plan

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CHAPTER 1 – INTRODUCTION

This report documents the work completed for the *Heavy-Duty Vehicle Idle Activity Study* (Grant Activities Description No. 582-17-74308-06) being conducted by the Texas A&M Transportation Institute (TTI) for the Texas Commission on Environmental Quality (TCEQ). This study assembled data regarding extended idling and the use of auxiliary power units (APUs) by long-haul heavy-duty vehicles in Texas for use in the Environmental Protection Agency's (EPA's) current emissions model, the MOtor Vehicle Emissions Simulator (MOVES). Unlike its predecessor MOBILE6, MOVES is capable of modeling long-haul truck extending idling and the use of APUs as separate categories of emissions sources (*1*). MOVES-based emission inventories use county-level long-haul truck extended idling and APU activity information to estimate emissions from these activities. MOVES uses a combination of local and default activity information for these two source categories. Appendix A provides a summary of the MOVES approach to estimate extended idling and APU usage.

In the past, TTI has developed and implemented a procedure to incorporate refined, local data into the MOVES-based process for estimating extended idling and APU usage emissions in Texas. This method has the benefit of providing improved, Texas-specific estimates of extended idle emissions for state inventories and other purposes. The TTI procedure currently uses 'base' truck idling information gathered in a 2004 study for TCEQ. To produce current emissions estimates, or to predict future extended idle emissions, modelers use growth factors to project truck hotelling activities. This method has been adopted for all emissions inventories developed for TCEQ and the Texas Department of Transportation (TxDOT) since 2004. Appendix B provides an overview of the TTI procedure for extended idling and APU usage.

This project updated the base idle and APU activity data, enhanced data sources to include data sources that have become available since 2004, enhanced and recalculated the spatial and temporal projections using the updated data, and developed an updated database for use with the MOVES model. TTI used a combination of information sources including previous studies, fine-grained vehicle activity data sets such as those produced by the American Transportation Research Institute (ATRI) and INRIX, and site visits to establish an up-to-date database of extended idling and APU use activities by long-haul combination trucks. The results were organized into a format consistent with the TTI-developed procedure for estimating current and future extended idling emissions across Texas. This study provides a new 'base' set of extended idle activity data to replace the 2004 data used by state agencies. The new 'base' data is consistent with any changes that may have occurred in the long-haul trucking industry within Texas since the previous (2004) study, especially changes in APU use, or timing and location of hotelling.

This document is organized into the four major tasks of the study. As such, it assembles in a single document, all the individual task reports generated over the life of the project, including a very brief chapter documenting the transmittal of the data electronically. Each chapter / task is described below.

Chapter 2 – Activity Data Collection Plan

Chapter 2 documents Task 2 of the study. Under this task, TTI produced an activity data collection plan for heavy duty vehicle long term idling and APU use that included all Texas counties. The activity data collection plan recommended methods for collecting/obtaining and analyzing the activity and related data necessary to meet the inventory development and long term idle activity database requirements. Existing data was included as appropriate (i.e., able to substantively improve the quality of the results in the data analysis plan). The following activities were included in the activity data collection plan:

- Assess methods to measure or quantify diesel idling activity;
- Assess methods to quantify activity from potential and existing control measures, strategies, or programs, including emerging idling emissions reduction technologies;
- Document how data collected will include sufficient temporal information to develop daily and seasonal variations;
- Document how data collected will include sufficient geographic information to develop activity estimates for each Texas county;
- Document how data collected or obtained will include appropriate data elements to extrapolate the data to all MOVES analysis years:1990 and 1999 to 2050;
- Document a list of the emissions-related vehicle characteristics to be included in the data collection;
- Identify relevant existing data sources for long haul combination trucks for the following parameters: source populations, operating profiles, vehicle age, and vehicle miles traveled (VMT);

- Document the process and methods to be used in Task 3 to collect new data for long term idling activity and APU use; and
- Document data collection methods, procedures and other data collection tools.

A Draft Activity Data Collection Plan was provided to the TCEQ Project Manager. Edits and revisions addressing TCEQ comments were made and a Final Activity Data Collection Plan was approved by the TCEQ Project Manager.

Chapter 3 – Activity Data Collection

Chapter 3 documents Task 3 of the study. Under Task 3, TTI collected the long term idle and APU activity and related data for long haul combination trucks, as documented in the Final Data Collection Plan. The Task 3 process and activities were consistent with the Final Data Collection Plan. A record was kept of all electronic files developed or used in conjunction with the completion of Task 3. All Task 3 activities were documented in a Progress Report which, along with the electronic data, was provided to the TCEQ Project Manager. The Progress Report included documentation of the activity data collection process, the data collected or obtained and a description of the electronic files.

Chapter 4 – Data Analysis and Long-Term Idle Database

Chapter 4 documents Task 4 of the study. Under this task, TTI analyzed the data gathered in Task 3 to produce updated long-term idle activity estimates and process the results into a file formatted for use with MOVES. Activities completed under Task 4 included:

- analyzing the activity data; and
- processing the results of the data analyses and developing MOVES compatible inputs for all Texas counties for all MOVES analysis years: 1990 and 1999 to 2050.

In addition to developing and providing the MOVES compatible input database, TTI documented all Task 4 activities for inclusion in this final report. Activities completed and documented include a description of the data analyses, the results of the data analyses, a description of the method used to develop the data file containing information needed for inputting the 1990 and 1999 to 2050 county-specific long term idle and APU information into MOVES county databases, and a description of model input information.

Chapter 5 – Emissions Inventory Development

Chapter 5 documents the development of emissions inventories using the data and associated revised procedures developed in Tasks 2 through 4. Under Task 5, TTI has produced 2017 combination long-haul truck idling emissions inventories using the previous (2004) truck idling data that include criteria air pollutants (CAP) and CAP precursors, as well as the hazardous air pollutants (HAP). TTI loaded modified long-term idle activity results reflecting the earlier (2004) truck idling data, into existing MOVES2014a county database files (CDBs) and other emissions inventory (EI) development files for analysis year 2017, and developed modified statewide 2017 emissions inventories for selected urban areas using the modified CDBs and inventory utility files.

A pre-analysis plan was prepared and approved by the TCEQ Project Manager documenting the MOVES modeling approach, inventory inputs, and inventory development procedures.

Activities completed under this task included:

- For analysis year 2017, incorporate the long term idle inputs into existing MOVES county databases and other inventory development utility files that were previously created to support development of the on-road 2017 Air Emissions Reporting Requirements (AERR) emissions inventories;
- Use the modified MOVES CDBs to develop emissions estimates for combination long-haul truck long-term idling and APU use, for selected Texas counties for analysis year 2017 based on the earlier (2004) for comparison with the 2017 results; and
- Process the emissions results into standard TCEQ on-road EI formats for Texas.

CHAPTER 2 – ACTIVITY DATA COLLECTION PLAN

INTRODUCTION

Chapter 2 documents Task 2 of the study. Under this task, TTI produced an activity data collection plan for heavy duty vehicle (HDV) long term idling and APU use that included all Texas counties. The activity data collection plan recommended methods for collecting/obtaining and analyzing the activity and related data necessary to meet the inventory development and long term idle activity database requirements. Existing data was included as appropriate (i.e., able to substantively improve the quality of the results in the data analysis plan).

Figure 1 demonstrates that the extended idling activities for a county over a specified period can be conceptualized through three key information sources.

- A - Number of HDV parking spaces by facility type.
- B - Idling factor, defined as the expected/average hours of extended idling occurring per HDV parking space over a specified time period.
- C - A statewide distribution of hotelling extended idling operating mode (either using the truck main engine, or electric or diesel APUs).

Using this conceptual process, TTI estimated and characterized these three information sources through the data collection, data assembly, and analysis process.

The data collection plan was based on the conceptual process outlined in Figure 1. The data collection plan enabled the team to estimate values for the number of parking spaces within a county, idling factors for different types of facilities, and the equipment used during idling. This plan identified the data sources to be used to derive this information, the information that would be extracted from them, and how key parameters would be calculated from the extracted information.

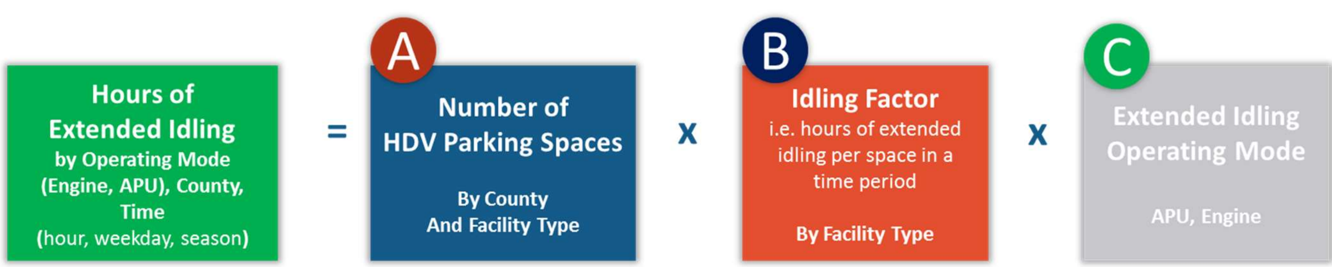

Figure 1. Characterization of Extended Idling.

Task Outputs

Figure 2 schematically illustrates the outputs of the task. For all Texas counties, the task produced estimates for the duration of hotelling: extended idling (truck main engine operation), diesel APU usage, electric APU usage, or other sources. The task also produced estimates for weekdays and weekends, and summer and winter seasons.

These data were estimated using a modeling approach that leveraged multiple existing data sources. Where necessary, data collected specifically for the study, was collected to fill data gaps, or validate model outputs. The modeling approach produced the required estimates of hotelling activities, but also provided confidence intervals and errors for the estimates to ensure the validity of the models and modeling assumptions.

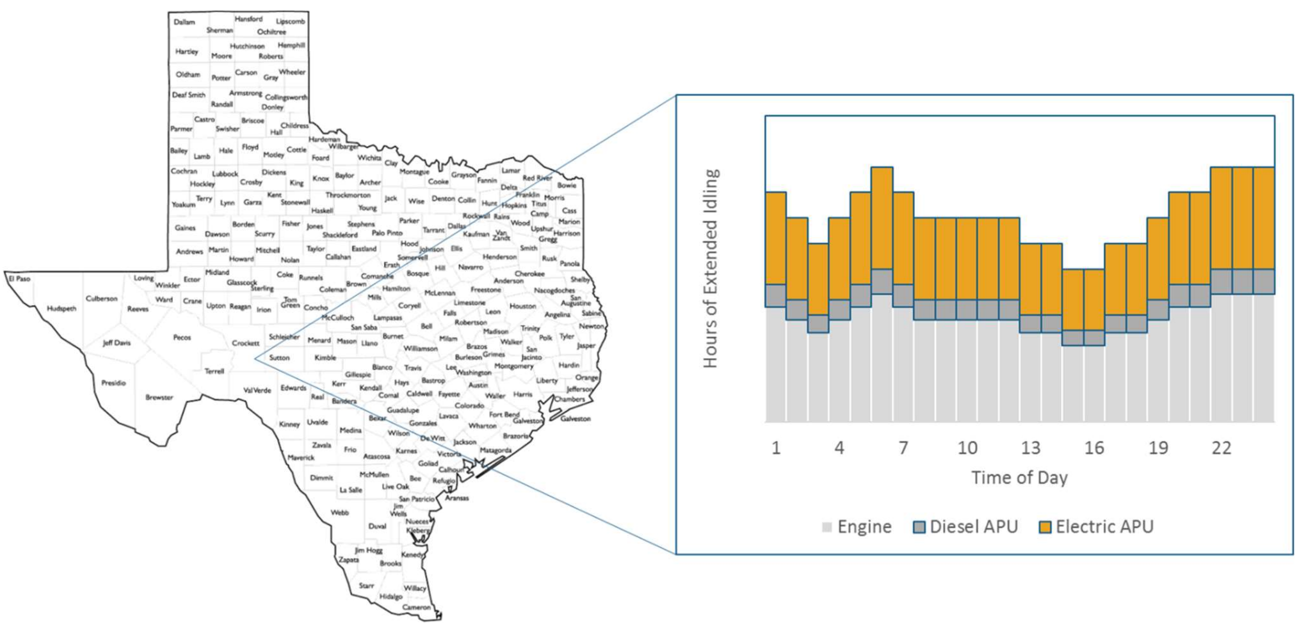

Figure 2. Conceptual Outline of Study Outputs (Conceptual Data).

HOTELLING

For the purpose of emissions estimations, "hotelling" is defined as any extended period of time that drivers spend inside their vehicles during the mandatory off-duty time during long-haul activities by combination heavy-duty trucks (source type ID 62). Hotelling hours are included in emissions inventories to account for use of the truck engine (i.e., extended idling) or APU usage to power air conditioning, heat, and other accessories.

The data collection plan described in this chapter will address hotelling including extended idling and APU usage. Following the conceptual process introduced in the previous chapter, TTI has divided the data collection plan for the extended idling into three parallel processes supporting the calculation of: 1) the number of parking spaces by facility type; 2) idling factor by facility type; and 3) the availability and use of APUs during extended idling. Each section will begin with a conceptual design of the methodology followed by more details on the data and how the identified data sets will be used at each step of the process. Appendix C provides an overview of the data sources that TTI is planning to obtain or collect.

1. DETERMINE NUMBER OF PARKING SPACES

Figure 3 shows the conceptual methodology that TTI has developed to estimate the number of parking spaces of a specific facility type for all counties in Texas. The process involves six major steps outlined in the following.

Step A1. Assemble a List of Facilities – Work in this step includes compiling a list of existing facilities where hotelling activities occur. Previous studies have found that the majority of the hotelling activities occur at commercial truck stops and, to a lesser extent, at TxDOT-maintained and operated rest areas. TTI has identified the following data sources to build a comprehensive list of the facilities. At a minimum, the list will include the name, address, and coordinates for the listed facilities. Additional information such as amenities and number of truck parking spaces will be included where available.

- *TxDOT-maintained rest areas:* TxDOT maintains updated information of these rest areas that includes a map and a list of the facilities specifying their locations and amenities.[1] This list is the main source of information for the rest stops. TTI will contact TxDOT to verify the information on this list.

- *Web-based databases:* Web-based services such as TruckMaster Fuel Finder and www.TruckStopInfoPlus.com maintain a searchable database of the truck stops throughout the U.S. and Canada. In addition to location, these databases provide information on the amenities. These databases cover rest areas and a majority of major-chain commercial trucks stops and independent trucks stops. TTI has downloaded the list from the two previously mentioned services. TTI will scan for other similar databases and download any available information from them.
- *TCEQ Petroleum Storage Tanks Registrations:* TCEQ maintains a searchable database of the regulated underground and aboveground petroleum storage tanks. This database is available through TCEQ's Central Registry Query webpage. The database virtually covers all the fueling stations in Texas that use an underground storage tank. TTI will download the list of the registered facilities and extract the location and other relevant information.
- *GIS databases from Texas Metropolitan Planning Organizations (MPOs):* Some Texas MPOs, such as the North Central Texas Council of Governments (NCTCOG), maintain a list of the trucks stops operating in their jurisdiction in a GIS format. TTI will contact the major MPOs in the state and obtain their databases where available.

The facility lists derived from these sources will be combined into a single master list of facilities. TTI will perform validation of the list in Step A2.

Step A2. Validate Location Information – This step will validate the information included in the master list of facilities from Step A1 to develop an updated master list of facilities of interest, with accurate locational attributes. In this step, TTI will review the master list, and verify that each entry represents a location that is currently operational, in which trucks could conceivably conduct hotelling activities. The validation of information will include an examination of locations via a two-phase process: Phase 1 -

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[1] http://www.txdot.gov/driver/travel/rest-areas.html?CFC__target=http%3A%2F%2Fwww.dot.state.tx.us%2Fapps-cg%2Fsafety_rest_areas%2Fsralocations.htm

cross-examination of the database from Step A1 in a GIS environment (satellite imagery, comparison with data from previous studies and existing data sets); and Phase 2 - telephone calls to verify current status or operations of facilities in case of inconsistencies found in Phase 1. The following data sources and processes are identified for the purpose of this step.

- Comparison with previous studies: Data from prior studies such as TTI (June 2003), Eastern Research Group (ERG) (ERG, Cambridge Systematics Inc., and Alliance Transportation Group, Inc., August 31, 2004), Alamo Area Council of Governments (AACOG) (October 31, 2011), and Capital Area Council of Governments (CAPCOG) (December 2013) will be used to verify facility information in the master list.
- Satellite imagery: TTI will visually check each location on up-to-date satellite imagery such as google maps. The main purpose of this check is to validate the existence of the facility and validate the master list information. Satellite imagery will also be used to verify or obtain information on the number of parking spaces at each facility.
- Cross-examination of Step A1 lists: TTI will check and cross check the facility information on all the lists compiled in Step A1, previous studies, and satellite imagery. If a facility appears to be missing information on one or more of these lists, it will be flagged for further investigation.
- Telephone calls: TTI staff will contact a random sample of facilities on the master list to verify the information gathered in previous steps. TTI will also call the facilities flagged during the cross-examination.

Researchers will update the master list by removing duplicates, removing non-operational facilities, and filling in missing information. This validated list of facilities will be used in the development of an expanded data set of all facilities in Step A3.

Step A3. Build a Data Set of Facilities – This step will build an expanded database of information related to each of the facilities by identifying key attributes such as the number of parking spaces, location and county, adjacent roadway type and AADT, amenities at facility, area type, and other county-level attributes (such as population, nonattainment status, existing idling restrictions, etc.). Researchers anticipate that several of these attributes will be collected as part of Steps A1 and A2. TTI will review and assemble these data and conduct additional information searches (including visual inspection via GIS/satellite imagery or supplementary telephone calls) to establish the required attributes for each facility for the list created in Step A2.

Step A4. Define Facility Types – This step will review the attributes of the facilities assembled in Step A3 and develop a typology of facilities. This will allow for the grouping of facilities into categories that will possibly experience similar types and levels of hotelling activity. For example, a small rest area in a rural setting may experience very different levels of hotelling and extended idling than levels typically experienced at a commercial truck stop in an urbanized area adjacent to an interstate highway. In this task, TTI will conduct a clustering analysis to identify logical groupings of facilities based on attributes quantified in Step A3, such as location type (urban/rural), facility type (truck stop vs. public rest areas), characteristics of adjacent roadways (freeways vs. rural roads), and number of parking spaces. A proposed typology of facilities will be developed using a clustering analysis methodology such as k-nearest or fuzzy clustering. The resulting facility types including the number will be refined and finalized in discussions with the TCEQ project manager.

Step A5. Group Facilities – In this step, the data set of facilities developed in Step A3 will be grouped based on the typology developed in Step A4, and additionally categorized by county. The output of this step will be a countywide listing of facilities where hotelling extended idling occurs, categorized by facility type.

Step A6. Calculate Number of Parking Spaces – In this step, the data related to number of parking spaces for each facility (from Step A3) will be used in conjunction with the county-wide grouping of facilities (from Step A5) to quantify the number of parking spaces per facility type for each county in Texas.

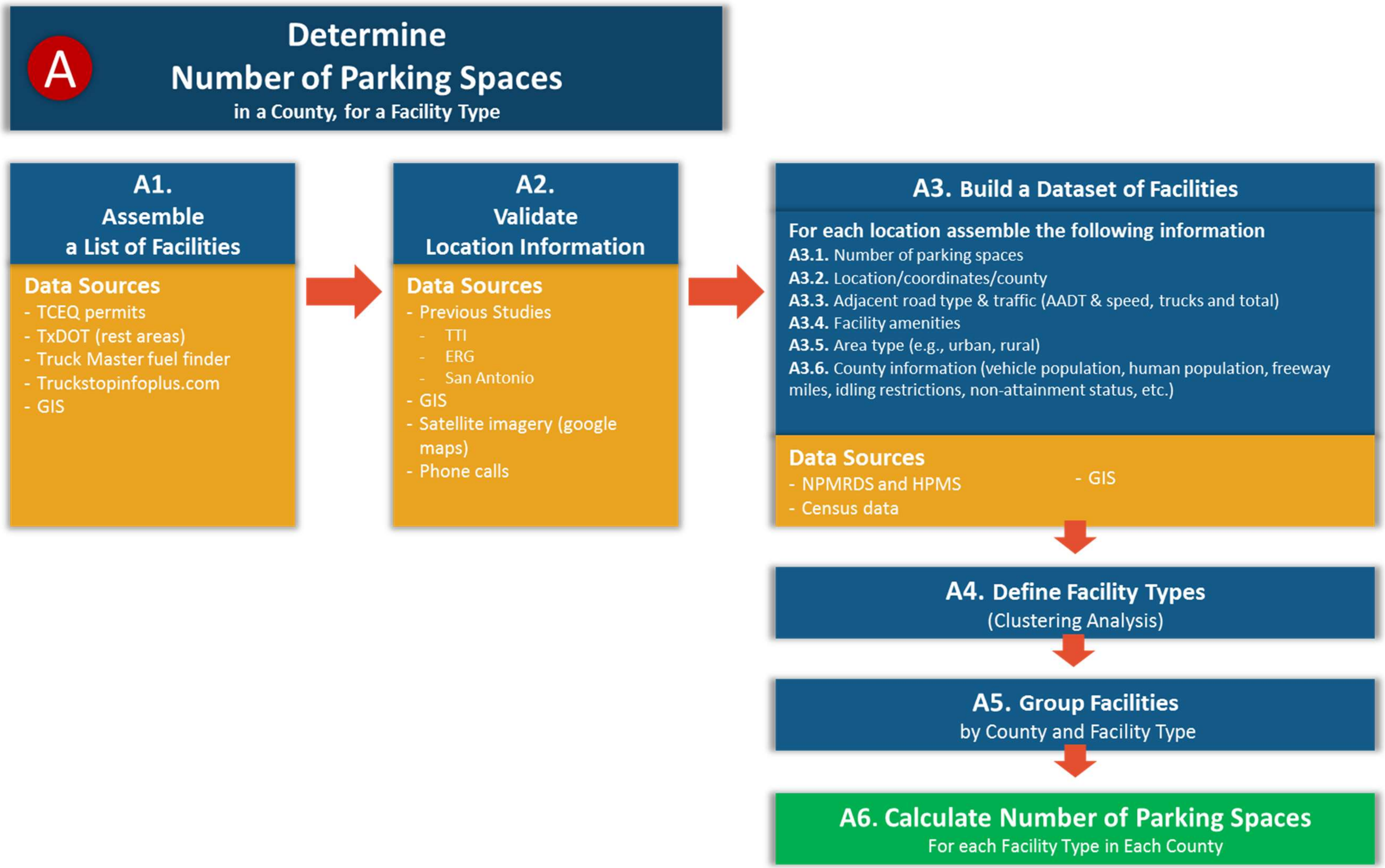


Figure 3. Data Collection Plan and Methodology for Number of Parking Spaces.

2. Determine Idling Factor

Figure 4 shows the conceptual methodology for estimating the idling factor of a specific facility type. The idling factor is defined as the expected number of hours of truck idling occurring on a parking space during a specified time period. TTI will use a mixture of fine-grained vehicle movement data, findings from previous truck idling studies in Texas, and a limited number of site visits to estimate and validate these idling factors. The process involves six major steps as outlined in the following.

Step B1. Assemble Information from Previous Studies – This step will extract and organize relevant data items and information from previous truck idling studies in Texas. TTI has identified four relevant studies as listed in Figure 4. From these studies, TTI will extract the facility name, location (address and coordinates), amenities, number of truck parking spaces, and other relevant information. TTI will search for other similar U.S.-based studies. TTI will include these studies on the list if their information is applicable to the scope of this project. TTI will review the data collection and analysis methods of all the selected studies to identify potential gaps in them.

Step B2. Extract Parking and Idling Activity Parameters from Previous Studies (Sub-Steps B2.1. and B2.2) – A review of the previous studies from Step B1 shows that these studies recorded observations made during their respective data collection efforts in terms of two related parameters:

- B2.1. Parking activity or occupancy rate: reported as hourly distribution of percentage of occupied parking spaces. This information is reported either in an aggregated format (ERG 2004) or for individual facilities (CAPCOG/TTI 2013, AACOG 2011); and
- B2.2. Idling fraction: reported in terms of the hourly distribution of percentage of occupied spaces that hotelling extended idling is occurring. Similar to occupancy rate, this information is reported either in an aggregated format or for individual facilities.

TTI will extract these two parameters from the studies selected in Step B1, and will organize these by facility type consistent with Step A4. Researchers will assemble these hourly distributions in a consistent tabular format for use in Step B5.

Step B3. Use Fine-Grained Vehicle Movement Data to Extract Parking and Idling Activity Parameters (Sub-Steps B3.1. and B3.2) – This step deals with the use of fine-grained vehicle movement/activity data to extract parking and idling activity parameters to supplement the information assembled from previous studies (Step B2). In past studies, parking and idling activity estimation relied mostly on surveys and visual inspection of truck stops and other locations. The use of novel, fine-grained data sources such as INRIX and ATRI has the potential to greatly improve the accuracy, and spatial and temporal coverage of these estimates. Appendix C provides a summary of the major sources of fine-grained truck movement data (INRIX, ATRI, and HGAC/TTI) that TTI is planning to use in this study. TTI has contacted the data providers and obtained samples of these data. ATRI and INRIX both produce and sell different transportation data products; however, their underlying data is the location of individual trucks from a sample of on-road trucks. ATRI and INRIX have stated that their samples include 8-10% of the active on-road truck population; although the sample size varies by time and location.

The following describes how TTI will extract parking and idling activity parameters from these data sets.

- *B3.1. Parking activity or occupancy rate*: Using GIS, TTI will extract this information by overlaying truck locations obtained from vehicle probe data (INRIX and/or ATRI vehicle probe data) with a sample of 10 facilities of interest and filtering out the moving portions; i.e., only keeping parking activity. The facility sample will include a mixture of facilities from Step B1 (i.e., previous studies) and other facilities representing facility types or area types not represented in the Step B1 sample. Researchers will further filter this subset of data to keep only parking activity that continues longer than 15 minutes. At a minimum, this data will cover a five-day period. TTI will analyze the resulting subset to extract hourly distribution of hours parked and number of trucks (i.e., sample) for each target location. This hourly distribution will be scaled based on the maximum observed occupancy rates from previous studies of the same type. The scaled parking information represents the *sample occupancy rate* for a facility.
- *B3.2. Idling fraction*: TTI has discussed the extraction of idling events with INRIX and ATRI personnel. TTI will purchase the INRIX and ATRI data with a spatial extent required to encompass the facilities identified in Step B3.1. The

observations will come from the same time periods of Step B3.1. TTI will analyze these data to extract the hourly distribution of the number of trucks and idling hours for each target location. This hourly distribution will be scaled based on the maximum observed idling rate from previous studies of the same type. The scaled idling information represents the *sample idling fraction* for a facility.

Step B4. Conduct Site Visits to Select Facilities (Sub-Steps B4.1. and B4.2 in Figure 4) – In this step, TTI will conduct site visits or surveys to develop a sample of facilities identified from Step B3. These observations will 'ground truth' the extended idling activities at these locations compared to the estimates obtained using the INRIX and ATRI data. The visits/surveys will be designed to estimate the temporal pattern of extended idling and APU use. It is envisioned that all the facilities will be covered, with 24 hours of observations being conducted for each. TTI will collect the following information:

- Number of trucks parked;
- Number of trucks idling; and
- Number of truck parking spaces.

Each 24-hour observation will include six visits during a weekday to each site for the following time periods:

- 10:00 p.m. - 2:00 a.m.;
- 2:00 a.m. - 6:00 a.m.;
- 6:00 a.m. -10:00 a.m.;
- 10:00 a.m. - 2:00 p.m.;
- 2:00 p.m. -6:00 p.m.; and
- 6:00 p.m. - 10:00 p.m.

Step B5. Combine, Validate, and Develop Representative Distributions for Parking and Idling Activities (Sub-Steps B5.1. and B5.2 in Figure 4) – In this step researchers will examine the sample distributions from Step B3 and refine them based on the data extracted from Step B1 (specifically the data from individual sites) and data collection results in Step B4. TTI will examine the hourly sample distribution for each facility type, compare them with the information from Steps B1 and B4, and make necessary adjustments to develop a series of representative occupancy rates and idling fractions.

Step B6. Estimate Idling Factor by Facility Type – In this step, the distributions of hours parked/occupancy and idling fractions will be combined to calculate idling factors (i.e., daily hours of idling per parking space) by facility type. This will be performed by multiplying occupancy rate by idling fraction for each hour of the day. This information, combined with the county-level estimates of parking spaces by facility type (from Step A), will allow for the estimation of extended idling by county in Texas.

Note that the Steps B1 – B5 are rooted in the identification and characterization of individual facilities. This ensures a logical, mechanistic, and robust data collection and analysis methodology. However, this study and the analysis methodology will estimate county-level extended idling activities. These will be generated by aggregating the estimates for each facility into county-level estimates (Step B6). This aggregation step, along with an understanding of biases and errors during the analysis phases will provide a robust, accurate, and efficient methodology for estimating county-by-county extended idling activities.

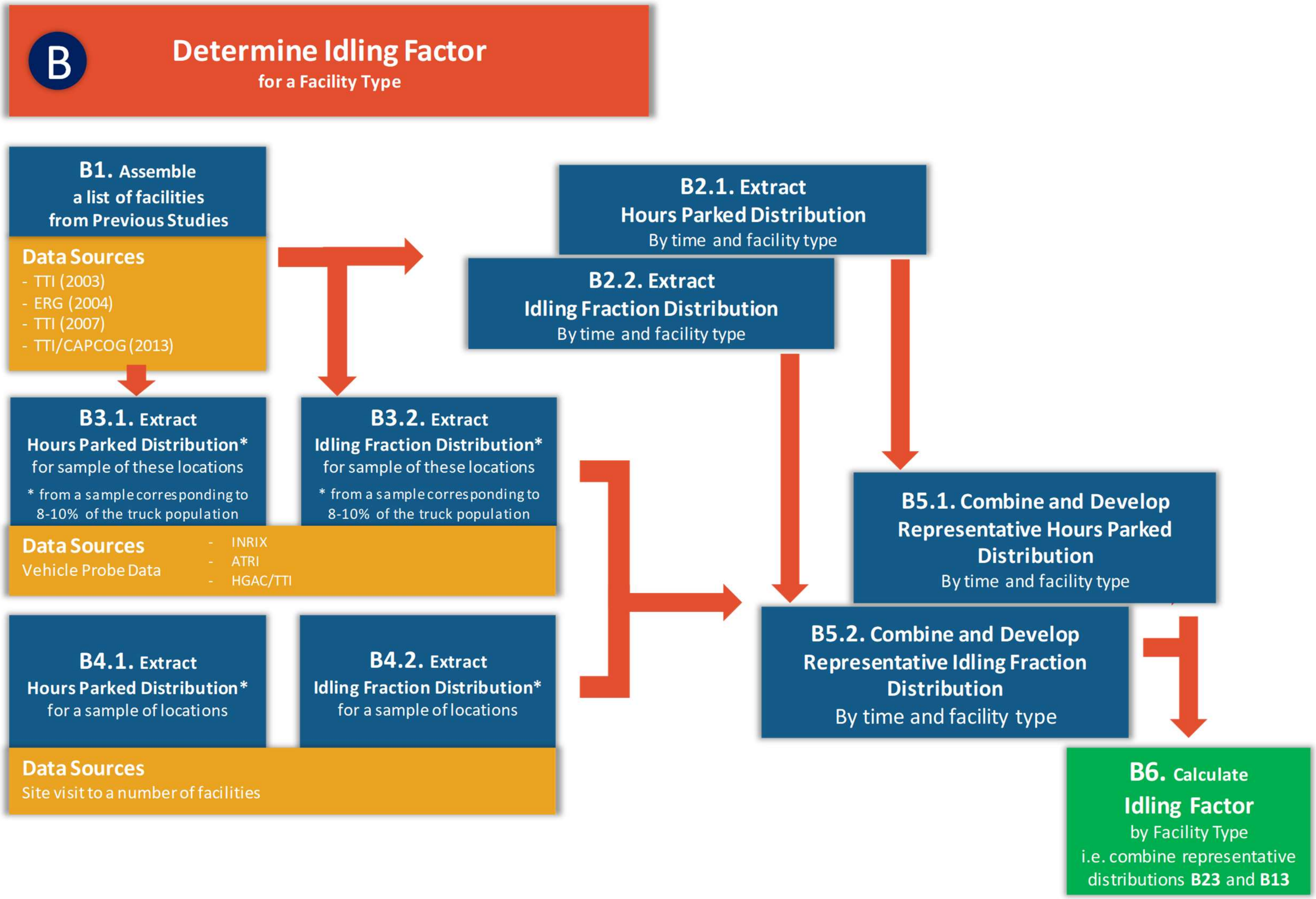


Figure 4. Data Collection Plan and Methodology for Developing Idling Factors.

3. APU Availability and Use

Estimates of APU use will be driven by the *a priori* assumption that APU use does not vary throughout the state. This assumption is logically consistent with long-haul combination truck activities — by definition, long-haul trucks move long distances throughout the state (and among states). Therefore, the 'types' of trucks (in the context of the types of APUs fitted to trucks) will be well mixed throughout Texas. Conceptually, this is the same robust assumption that is made when estimating on-road emissions via a statewide 'long-haul truck' age class data.

TTI will construct the initial analysis around this assumption, but the data collection methodology will also be designed to test its validity.[2] The data collection plan will involve the following initial steps.

Step C1. Collect APU specifications (current and past designs). Data collection will include sales information; and nationwide and Texas studies detailing the types of APUs fitted to long-haul trucks.

Step C2. Conduct a historical review of the APU options offered as standard and options on newly purchased trucks. Data will be obtained from truck and APU manufacturers.

Step C3. The information from Step C1 will be related to the age distributions of the Texas long-haul fleet (obtained via registration data).

Using the outputs from Steps C1 to C3 TTI will:

Step C4. Survey a cross section of haulage companies operating in Texas for the types of APUs installed on their long-haul truck fleet. The survey will be directed toward a representative cross section of haulage companies (both owner operators and larger haulage companies).

This iterative, hierarchical study design will ensure the resources available for the study are allocated optimally to address the ultimate research objective. Iterative modifications to the research plan will be discussed with the TCEQ sponsor and justified in the context of quantitative information obtained through Steps C1 through C4.

[2] For example, although the APU specifications of trucks *may* be consistent throughout the state, it is also possible that APU usage is driven by regional and seasonal differences in climates that may affect whether an APU is used in preference to main engine idling or whether, under certain circumstances, some drivers preferentially use *no* auxiliary power supply.

Conclusions

The data collection plan described in this document is designed to outline the data collection activities necessary to accurately estimate long-haul truck extended idling activities in Texas. The required outputs of this study are well defined, and have been used to estimate extended idling emissions in Texas since the advent of MOVES in 2003. TTI recognizes the importance of maintaining consistency of extended idling emissions estimation methods for regulatory purposes. This data collection plan is designed to provide cost effective and accurate activity data for this purpose.

The data collection plan is designed to increase the cost effectiveness of data collection efforts required to estimate accurate hoteling extended idling across the state. Since the last data collection effort (2004), a number of emerging data sets have become available that have the potential to increase both the accuracy and cost effectiveness of developing hoteling activities. The use of these data sets requires increased analytical effort, and a more complex data collection plan relative to previous studies. TTI is confident that over the long term, this will provide more accurate and representative estimates of hoteling activities, relevant to the current and future outlook of long-haul activities throughout the state.

Although the proposed data collection plan addresses the need for more cost effective data collection and analysis methods, TTI also recognizes the importance of the historical consistency of hoteling activity estimates (and emissions) in Texas. For these reasons, the data collection plan is designed to be consistent with data and methods employed in previous studies.

CHAPTER 3 – ACTIVITY DATA COLLECTION

REVIEW OF STATE-OF-THE-PRACTICE

The TTI team conducted a review of the existing documents and datasets to understand the current state-of-the-practice pertaining to long-haul truck activity data identification, hotelling idling estimation processes, and various changes in the regulations governing long-haul driving hours.

PRIOR AND ONGOING TEXAS STUDIES

Various efforts have been undertaken in Texas aimed at studying and collecting long-haul truck idling activity information. Prior studies included: TTI (June 2003); Eastern Research Group (ERG); Cambridge Systematics Inc. and Alliance Transportation Group, Inc. (August 31, 2004); Alamo Area Council of Governments (AACOG) (October 31, 2011); and Capital Area Council of Governments (CAPCOG), which used data collected by the TTI team (December 2013). The 2003 TTI and 2004 ERG studies focused on developing heavy-duty idling activity and emissions profiles as it pertains to the U.S. Environmental Protection Agency (EPA) MOBILE6 model. (*2*, *3*, *4*, *5*)

The 2003 TTI study developed a study design for quantifying truck idling emissions in Texas and to produce initial estimates of the magnitude of truck idling emissions in Texas. The TTI study focused on the Beaumont Port Arthur (BPA) Area idling locations such as truck stops, public rest areas, industries, ports, and intermodal facilities. Using BPA as a case study, the results were scaled to all the metropolitan areas in Texas. It was found that approximately 23 tons/day (tpd) of oxides of nitrogen (NO_x) emissions are emitted in the major metropolitan areas in Texas due to extended truck idling. The contribution of the nonattainment and near nonattainment areas is approximately 13 tons per day of NO_x emissions.

In 2004, ERG developed a statewide on-road heavy-duty vehicle (HDV) extended idling activity database by conducting surveys at truck stops and travel plazas, state-maintained rest areas and travel centers, commercial marine ports, airports, and intermodal rail yards. Emissions results for the 2004 base year were 29.61 tpd.

Other studies, such as the AACOG study, studied the eight-county region in the San Antonio area in 2010. AACOG conducted visual surveys of engine idling practices by long-haul truck drivers at truck stops. The study also collected time of day variation of idling activities at truck stops. The idling survey data collected was and analyzed and provided in an organized electronic format that was readily incorporated into on-road inventory development with the MOVES model. As a follow-up to 2010 study, AACOG conducted a truck idling data collection campaign in summer and fall of 2018. The spatial and temporal allocation of long-term heavy-duty truck idling will be collected through the survey to provide data needed to calculate emissions.

CAPCOG, with the assistance of TTI, developed a regional inventory of extended idling parking spaces for 2006, 2008, and 2012 along with estimates of idling activity and associated emissions. As part of this study, TTI conducted: a) initial site visits to 16 potential truck idling locations in Bastrop, Caldwell, Fayette, Hays, Travis, and Williamson counties; b) 176 observations at seven truck stops in Caldwell, Hays, Travis, and Williamson counties; c) 10 observations along interstate frontage roads in Hays, Travis, and Williamson counties; d) 14 observations at Walmart stores in Hays, Travis, and Williamson counties; and e) 118 interviews with truck drivers.

EPA On-Road Models

In the MOBILE6 model, long duration idling is defined as the operation of the truck's propulsion engine when not engaged in gear for a period greater than 15 consecutive minutes, except when associated with routine stoppages due to traffic movement or congestion (*6*). After reviewing the impact of fuel consumption on the conversion factor for Class 8 trucks and the impact of the conversion factor on the g/mile emissions factors for Class 8 trucks produced by MOBILE6, the research team believes long-duration truck idling emissions account for not more than 3.4 percent of the total emissions for Class 8 trucks for any criteria pollutant or precursor in MOBILE6.

In MOVES, the definition of extended idling is "characterized by idle periods more than an hour in duration, typically overnight, including higher engine speed settings and extensive use of accessories by the vehicle operator." During normal road operation, truck idling can occur while waiting in traffic or short stop delivery. Frequent stops can contribute to the overall emissions and are already included in the "normal vehicle hours of operation." Unlike the idling for short or frequent stops, extended idling periods are over an hour rather minutes (*7*).

In the current version of the MOVES model (MOVES2014), the total hours of driving are estimated by using the national estimate of total vehicle miles traveled (VMT) by long-haul combination trucks divided by an estimated average speed. It is assumed that on average 10 hours were spent driving per long-distance trip while on average eight-hour rest times were spent during each trip. The total hours of Hotelling are then estimated as total hours of driving divided by average time driving per trip and multiplied by the average time hotelling per trip. The national average hotelling rate is calculated by national total hours of hotelling divided by the national estimate of total VMT by long-haul combination trucks on rural restricted access roads (*8*). If users want to supply hotelling hours for runs in MOVES2014a, they must populate the HotellingHours table manually. For future versions of the MOVES model, EPA has proposed using diesel long-haul combination truck VMT from both rural and urban restricted access roads for estimating extended idling hours (*9*).

Engine Idling and Relevant Regulations

According to the American Trucking Associations (ATA), every year about 10.5 billion tons of freight is moved in the U.S. on trucks. To move this tonnage, there are 3.4 million heavy-duty Class 8 trucks and 3.5 million truck drivers (*10*) operating in U.S. With such a high volume of trucks operating on highways, there was need for regulation for fair competition in the trucking industry. Passage of the Motor Carrier Act in 1935 gave the Interstate Commerce Commission (ICC) authority to regulate the motor carriers and drivers involved in interstate commerce. Although most of regulations were aimed at ensuring fair competition and safety, anti-idling regulations and other emissions reduction initiatives continue to influence drivers and truck carrier operations on a daily basis (*11*).

Hotelling associated with long-haul operation are heavily influenced by the regulation governing the hours of service for long-haul drivers. Since the focus of this study is identifying truck idling (hotelling) locations and estimating hotelling hours associated at each location, it was prudent to identify changes that have occurred in the trucking industry affecting hotelling operations.

Table 1 provides a summary of events relevant to idling emissions that have occurred since 2004.

Table 1. Changes in the Long-Haul Trucking Industry Since 2004.

Year	Summary
2004	New driver Hours of Service (HOS) rules, which took effect January 4, 2004, effectively reduced on-duty time for drivers and increased the time a driver must take off between shifts.
2006	There has been heavy "pre-buying" of trucks and tractors in anticipation of the new 2007 engine and fuel standards. The 2007 truck/tractors are expected to cost more and get less miles per gallon. The thought was that anyone who wants a new truck in the next two years will have ordered it in time to take delivery by December 31, 2006. That way, they do not have to endure the higher cost of buying, maintaining, and fueling a 2007 model with its new engine, after-treatment, and the need for untested ultra-low-sulfur diesel (ULSD) fuel.
2008	2008 average fuel prices peaked at over $4.70 in July. Soaring diesel fuel prices amid a continued weakness in freight volume made 2008 one of the worst years ever for the U.S. trucking industry,
2009	Trucking industry tries to recover from a recession. In late 2009, as part of a settlement agreement, the Federal Motor Carrier Safety Administration (FMCSA) agreed to re-visit the HOS rules.
2010	Comprehensive Safety Analysis (CSA), FMCSA's new regulatory framework made its debut this year, with full implementation slated for 2011. In December, FMCSA issued changes to the HOS rules. The proposed changes include potentially decreasing driving and on-duty times, and extending the restart provision.
2011	In December, the FMCSA issued a final rule, which changed several key provisions in the HOS.
2013	Changes to the final HOS rules went into effect in July 2013. The new rules limit use of the 34-hour restart and requires a minimum 30-minute break before driving after eight hours on duty.
2014	Restart provisions were suspended by Congress in December and required a study on the impacts of the HOS restart provisions.
2015	In December 2015, the FMCSA issued a final rule on electronic logging devices (ELDs), which sets a timeline of two years for fleets and drivers using paper logs to convert to ELDs for HOS tracking. ATRI released the first of a series of technical memoranda on the topic of truck parking in September 2015 highlighting driver perceptions and valuations for locating available parking.
2017	FMCSA's mandatory ELD rule for tracking HOS went into effect on December 18, 2017. An ELD automatically records driving time, for easier, more accurate HOS recording by synchronizing with a vehicle engine. This was congressionally mandated as a part of MAP-21 and is intended to help create a safer work environment for drivers, and make it easier and faster to accurately track, manage, and share HOS records.

OTHER RELATED STUDIES

A study completed in 2004 explored the characteristics of long-haul truck idling throughout the nation. Researchers surveyed long-haul truck drivers at six locations operated by a private truck stop chain. This survey showed an average total driving distance of 112,000 miles annually with an average of 10.4 hours of driving on each day. Based on the drivers' responses, it was noted that they spent 5.9 hours idling. It was specifically estimated that idling was associated with an average of 34% of total engine run time, changing from 29% in moderate seasons to 39% in winter. The entire idling activity led to a consumption of 1,600 gallons of fuel per year, which could increase to more than 3,400 gallons per year for 10% of the truck drivers. This study indicated the importance of studying idling activity in terms of air quality as its impact is usually underestimated (*12*).

In 2006, the University of California, Riverside (UC-Riverside) conducted a study for the California Air Resources Board (CARB) investigating the activity of heavy-duty diesel trucks to validate the CARB's emissions factor (EMFAC2002) model. This study used the data from 270 electronic computer modules (ECMs) to perform the analysis. The results showed heavy-duty diesel vehicles commuted an average total distance of 392,975 miles during the study period while experiencing 29.4% of the time at idling (*13*).

Another study by West Virginia University in 2006 focused on idling emissions from heavy-duty diesel vehicles. The dataset used in this study was collected by the WVU Transportable Emissions Measurement Laboratory (Translab) in Riverside, CA. This data covered 75 Class 8 heavy-duty diesel vehicles including two types of vehicles with electronic fuel injection (EFI) and vehicles with mechanical fuel injection (MFI). It was found that the fuel management system might affect the rate of carbon monoxide (CO), hydrocarbons (HCs), particulate matter (PM), and NO_x. However, there was no relative impact on carbon dioxide (CO_2) and fuel consumption. Additionally, it was estimated that the use of air conditioning could increase idling emissions and fuel consumption by 25%. This study primarily examined the variations of idling emissions under different scenarios (*14*).

In 2008, a study conducted by North Carolina State University for Volvo Trucks of North America investigated the variability of idling activity over single or team drivers. A total of 20 long-haul trucks were studied and divided into two groups of single or team drivers. It was estimated that the total idling time for single drivers was approximately 2,130 hours, while 70% of that (1,520 hours) were extended idling (more than 7 hours).

This percentage decreased to 30% for team drivers. Additionally, the APU usage was cut by half when there were a team of drivers (*15*).

Cambridge Systematics, working with ERG, UC-Riverside, and the Volpe Center, is developing a guide for transportation practitioners on methods, procedures, and data sets needed to capture commercial vehicle activity, vehicle characteristics, and operations to assist in estimating and forecasting criteria pollutants, air toxics, and greenhouse gas (GHG) emissions from goods and services movement. The guide will enumerate the various sources of truck data available, and how the data can be obtained and used to support emissions modeling using the MOVES model and other methods. Case studies in the guide will highlight new and emerging data sources, or new uses of existing data, to develop information that is not widely available to most practitioners. Case studies are being developed focusing on (1) developing truck-specific speed distributions; (2) developing improved local data on truck starts and extended idling; (3) developing location-specific truck age distributions; and (4) developing a library of drive cycles and operating mode distributions relevant to different contexts such as ports, warehousing/distribution centers, and border crossings. The project is investigating a variety of "big data" sources. This study will be completed in June 2018 (*16*).

Idling Location Identification and Characterization

The focus of this effort was to identify the potential hotelling idling sites (hotelling locations) in Texas, which included truck stops, rest areas, travel centers, and picnic areas. For each idling site, the TTI team collected information such as location (latitude, longitude, and address), number of parking spaces, availability of over-night parking, and amenities. The information was used to identify sites for data collection, as well as for extrapolating the idling activity to the entire state. The list of the hotelling locations were assembled in a database which was submitted with the technical memorandum.

Idling Sites

TTI developed a comprehensive list of all the Hotelling locations with overnight parking capability in Texas. The potential Hotelling locations included:

- Rest areas and Travel centers;
- Picnic areas;
- Truck stops; and
- Walmart stores adjacent to a freeway.

Rest Areas and Travel Centers

This information was obtained from the Texas Department of Transportation (TxDOT). The information on the TxDOT website provided information on TxDOT-maintained safety rest areas, however the website did not provide information on how many truck parking spaces are available at each site. TTI reached out to TxDOT facilities staff to gather latest information on rest areas, picnic areas, and travel centers. TxDOT provided the most recent data available. The data included county, latitude and longitude, adjacent roadway, address, mile post, and car and truck parking spaces.

There were 80 rest areas in the original list that was provided by TxDOT of which five had no parking spaces for trucks. There were 11 travel centers listed in the TxDOT dataset of which three had no parking spaces for trucks.

Table 2 provides sample data for rest areas while Table 3 provides a summary of rest areas and travel centers.

Table 2. Sample Rest Areas Data.

County	Highway	Facility Name	Address	Mile Post	Storm Shelter	Parking (Car/ Truck)
Andrews	US-385 NB	ANDREWS CO. SRA				14/6
Bell	I-35 NB	BELL CO. SRA (NB)	17871 S. IH-35 S, Salado, TX 76571	281	YES	38/28
Bell	I-35 SB	BELL CO. SRA (SB)	16740 S. IH-35 S, Salado, TX 76571	282	YES	38/28
Brooks	US-281	BROOKS CO. SRA (in the median)				14/20
Callahan	I-20 EB	CALLAHAN CO. SRA (EB, E of Abilene)		296		14/10
Callahan	I-20 WB	CALLAHAN CO. SRA (WB, E of Abilene)		296		14/8
Cass	US-59 SB	CASS CO. SRA				14/8
Chambers	I-10 EB	CHAMBERS CO. SRA (EB)	31910 IH-10, Hankamer, TX 77560	814		30/26
Chambers	I-10 WB	CHAMBERS CO. SRA (WB)	31909 IH-10, Hankamer, TX 77560	815		30/26
Cherokee	US-69 NB	CHEROKEE CO. SRA				30/0
Coke	US-87 NB	COKE CO. SRA				12/5
Collingsworth	US-83 SB	COLLINGSWORTH CO. SRA				12/6
Colorado	I-10 EB	COLORADO CO. SRA (EB)	3561 IH-10, Columbus, TX 78934	692		24/24

Table 3. Summary of Rest Areas and Travel Centers by TxDOT District.

TxDOT District	No of locations
Abilene	7
Amarillo	2
Atlanta	3
Austin	3
Beaumont	3
Brownwood	2
Bryan	2
Childress	7
Corpus Christi	2
Dallas	2
El Paso	6
Fort Worth	3
Houston	2
Laredo	4
Lubbock	3
Lufkin	2
Odessa	7
Paris	5
Pharr	3
San Angelo	4
San Antonio	7
Tyler	3
Waco	4
Wichita Falls	4
Yoakum	4

Picnic Areas

For picnic areas, information was also sought from TxDOT. TxDOT provided a list that contained about 483 picnic areas, but without parking space information. Further communication with TxDOT facilities staff revealed that the TxDOT dataset does not include information on the number of truck parking spaces for the picnic areas. TxDOT staff stated that on average each picnic area is expected to accommodate approximately six cars and four trucks.

Table 4 shows sample data for picnic areas.

Table 4. Sample Picnic Areas Data.

County	Highway		Location Description
	System	Number	
Nolan	SH	70	20 mi south of Sweetwater
Nolan	SH	153	28 mi southeast of Sweetwater
Mitchell	IH	20EB	12 mi east of Colorado City
Mitchell	IH	20WB	12 mi west of Colorado City
Howard	IH	20	9 mi west of Big Spring
Howard	IH	20	9.6 mi west of Big Spring
Kent	US	380	18.6 mi west of Jayton
Scurry	US	84	13.2 mi west of Snyder
Mitchell	SH	208	6 mi south of Colorado City
Stonewall	US	380	11.4 mi west of Aspermont
Haskell	US	277	13.9 mi north of Haskell
Jones	FM	1082	At Fort Phantom Hill, Outskirts of Abilene CL
Kent	SH	70	3.1 mi north of Jayton
Stonewall	US	83	9.1 mi north of Hamlin
Shackelford	US	180	7.0 mi east of Albany
Shackelford	US	180	5.8 mi west of Albany
Borden	US	180	6 mi west of Gail
Scurry	US	180	10.4 mi east of Snyder

Truck Stops

Most of the information on truck stops is maintained by private franchises and individual owners. TTI staff started compiling a list by assembling information from the past studies conducted by different entities including ERG, TTI, NCTCOG, CACOG, and AACOG. The truck stop list developed from these sources was combined and duplicates were removed. TTI conducted an exhaustive internet search from different trucking websites to obtain updated lists of the truck stops. Following are the website sources that the TTI team used to extract information on truck stops.

Truck stop directory websites:

- Allstays.com
- Truckstopinfo.com
- truckstopsandservices.com

Franchise websites:

- flyingj.com (Flying J)
- loves.com (Love's)
- petrotruckstops.com (Petro Stopping Centers)
- tatravelcenters.com (Travel Centers of America)
- pilotcorp.com (Pilot Travel Centers)
- shell.com
- roadys.com

Table 5 shows the total number of truck stop identified from each source.

Table 5. Source Identification of Different Hotelling Locations.

Source	Number of Truck Stops
ERG	562
CAPCOG	42
AACOG	276
NCTCOG	153
Allstays.com	492
Truckstopinfo.com	367
Loves	8
Pilot	6
Flying J	3
Roady's	5

GIS Datasets

TTI staff identified various datasets and sources in the data collection plan that were potentially beneficial to the study. TTI used a subset of these datasets in quality assurance of truck stop. The TTI team reviewed these datasets and identified the following ones to contain information relevant to this study.

Freight Analysis Framework (FAF4) data

The Freight Analysis Framework (FAF), produced through a partnership between the Bureau of Transportation Statistics (BTS) and the Federal Highway Administration (FHWA), integrates data from a variety of sources to create a comprehensive picture of freight movement among states and major metropolitan areas by all modes of transportation. FAF version 4 (FAF4) provides estimates for tonnage, value, and ton-miles by regions of origin and destination, commodity type, and mode. Data are available for the base year of 2012, the recent years of 2013-2015, and forecasts from 2020 through 2045 in five-year intervals. Data may be accessed through the Data Extraction Tool, downloaded as a complete database, or in summary files. Figure 5 shows the long-haul truck volume data from the database for Texas.

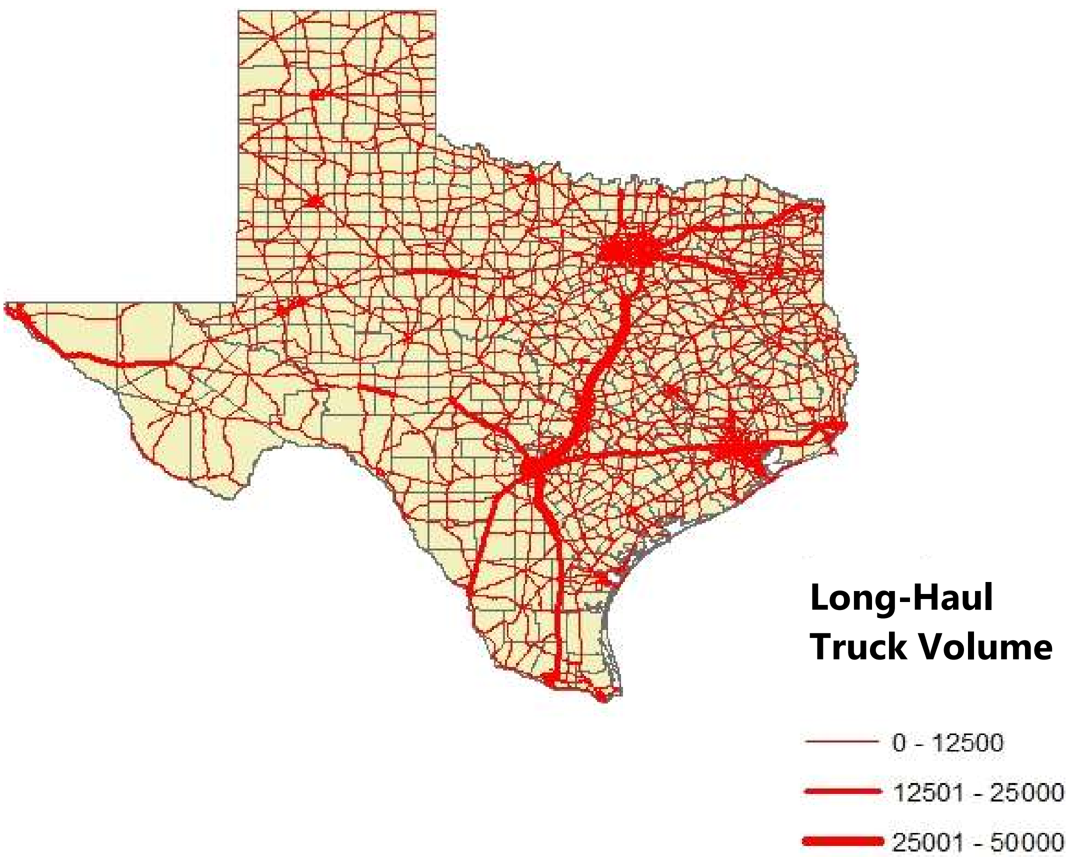


Figure 5. FAF4 Database Long-Haul Truck Volumes in Texas.

Long-haul truck volumes from the FAF are modeled from a series of estimates of network capacity, commodity flow and truck trip lengths and are not based on direct measurement. The FAF documentation cautions the user on the application of the estimates at the network link-level. As shown in Figure 5, the data only covers a subset of interstates and major roadways, and because FAF base years coincide with Census Bureau's Commodity Flow Survey (CFS) years and the CFS is collected in years ending in 2 and 7, the next generation of FAF will be based on 2017 CFS data (*17*). Similar to TTI's findings, the Coordinating Research Council study also recommended that FAF estimates be used to inform the relative contribution of long-haul truck VMT estimates, rather than using direct estimates of FAF long-haul VMT (*18*).

Average annual daily traffic (AADT) and long-haul truck volumes on the highways adjacent to the potential hotelling locations were extracted from FAF4 and included in the master idling location database. These data were envisioned to be used to QAQC the truck stop to identify potential utilization based on the truck volumes on adjacent roadways and also to eliminate truck stops or picnic areas based on low volumes and distanced from the FAF4 roadway network. However, an investigation by the TTI team revealed that the FAF4 truck volumes do not always represent the current active freight corridors in Texas. Therefore, researchers did not used FAF4 information in the hotelling idling analysis.

Other GIS Datasets

The TTI team also used information from the following geospatial datasets for quality assurance and geocoding the identified facilities (i.e., identifying county, metropolitan area, and other relevant information).

- TxDOT Highway Designations
- Texas Highway Freight Network
- Texas National Highway Freight Network
- TxDOT Roadway Inventory (HPMS Data)
- Texas Metropolitan Planning Organizations
- TxDOT Districts
- Texas Counties
- Texas Urbanized Areas
- Texas Council of Governments

QUALITY ASSURANCE OF DATA

Quality assurance (QA) and quality checks were performed on truck stop, rest areas, picnic areas, and travel centers tables before they were merged to create a master database. TTI staff focused on the truck stops in this process. This is because the truck stops are the dominant source of Hotelling idling. Following is a summary of QA steps taken by TTI staff.

1. Satellite imagery from Google maps and Bing maps were used to visually verify the accuracy of the position and number of spaces at each of the identified facilities. Additionally, any duplicates found across different datasets were removed using this procedure.
2. Google Earth maps were also used over different time periods to verify existence at each of the locations.
3. For locations where satellite imagery was not clear or non-conclusive, phone calls were made to confirm the existence and number of spaces.
4. A visual QA was conducted on some of the major corridors using Google Street View and Google Earth to visually explore the corridor for missing truck stops as Figure 6 shows. This exercise was conducted on the following stretches of different corridors listed in Table 6.

Table 6. Quality Check for Idling Locations Along Major Corridors.

Highway	Centerline Miles
I-35	260
I-10	191
US-290	150
I-20	303
Total	**904**

Figure 6. Google Street View Showing a Truck Stop on the I-35 Corridor near Italy, TX.

Further analysis of picnic areas using aerial imagery revealed that some of these locations may not be suitable for overnight parking or are not adjacent to the truck corridors (interstate and state highways). TTI staff used TxDOT Highway Freight Network information to identify picnic areas by selecting locations within one mile of a Texas freight corridor roadway segment. Figure 7 shows the picnic areas that are potential long-haul idling sites considered in this study.

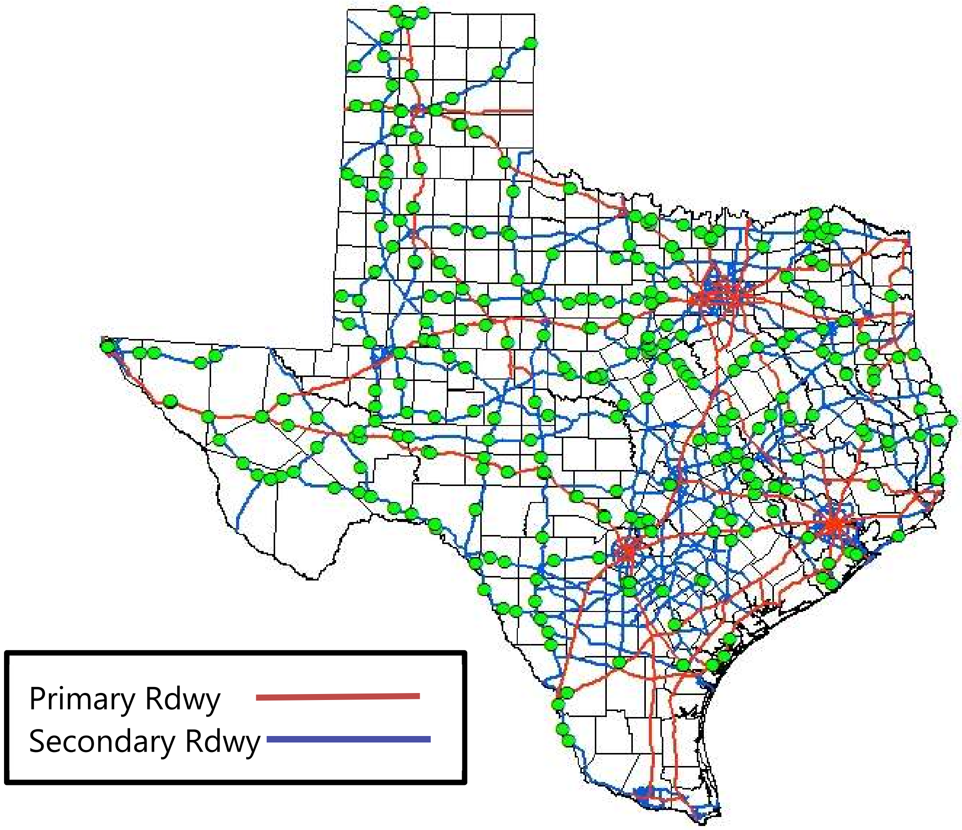


Figure 7. Picnic Areas Selected for the Truck Idling Study.

After each phase of the QA, the database entries and deletions were reviewed before making any changes. Table 7 shows the number of locations by facility type that were included in the master location database.

Table 7. Number of Hotelling Locations after Quality Assurance.

Facility Type	No of Facilities
Truck stops	700
Walmart stores	64
Rest area and travel center	84
Picnic area	330
Total	**917**

Note: Walmart stores were not part in the data collection plan, during the QA process Walmart locations were added into the master database.

Master Location Database

A master database was prepared with all the Hotelling locations where the characteristic parameters listed in Table 8 were available.

Table 9 provides a summary of the top 10 counties in terms of idling locations (ranked by total number of facilities). All 254 counties were found to have a least one Hotelling location and there was a total of 917 locations statewide. A complete list with all counties is included in Appendix A. Deliverable E-1 contains the complete list of locations and associated characteristics in electronic format. Figure 8 shows the overall distribution of idling locations in Texas. Truck stops appear to be clustered on the I-35, I-10, I-20, and I-45 corridors.

Table 8. Hotelling Location Characteristics.

Hotelling Parameters	Hotelling Parameters
• Latitude • Longitude • Street Address • Standardized Highway • Highway Exit Number • City • County • District • Zip code • Phone • Parking Spaces • Fuel • Open 24 Hours • Pavement • Diesel Lanes • Store • Weighing Scales • Restaurant • Bulk Diesel Exhaust Fluid (DEF)	• ATM • Internet • Showers • Restroom • Longue • Truck Stop Electrification • Propane • Vending Machine • Laundry • 2012 Daily All Truck Volumes (AADTT12) • 2045 Daily All Truck Volumes (AADTT45) • 2012 Daily Long-Haul Truck Volume (FAF12) • 2012 Daily Long-Haul Truck Volume (FAF45) • Urbanized Area Name • Area Type (Rural and Urban) • Nearest Metropolitan Area • Within Metropolitan Area • Council of Governments Name

Table 9. Number of Idling Locations by County.

County	Picnic Area	Rest Areas	Travel Center	Truck Stop	Walmart Store	Grand Total
Harris				72	9	81
Bexar				21	6	27
Dallas				20	6	26
Pecos	7	4		7	1	19
EL Paso	4	2	1	10	2	19
McLennan				16	1	17
Culberson	8	3		5		16
Wise	1	1		13		15
Tarrant				11	3	14
Smith	3			10	1	14
All Other Counties*	307	65	8	515	35	930
Grand Total	**330**	**75**	**9**	**700**	**64**	**1178**

* See Appendix A of this report for numbers for each county in Texas.

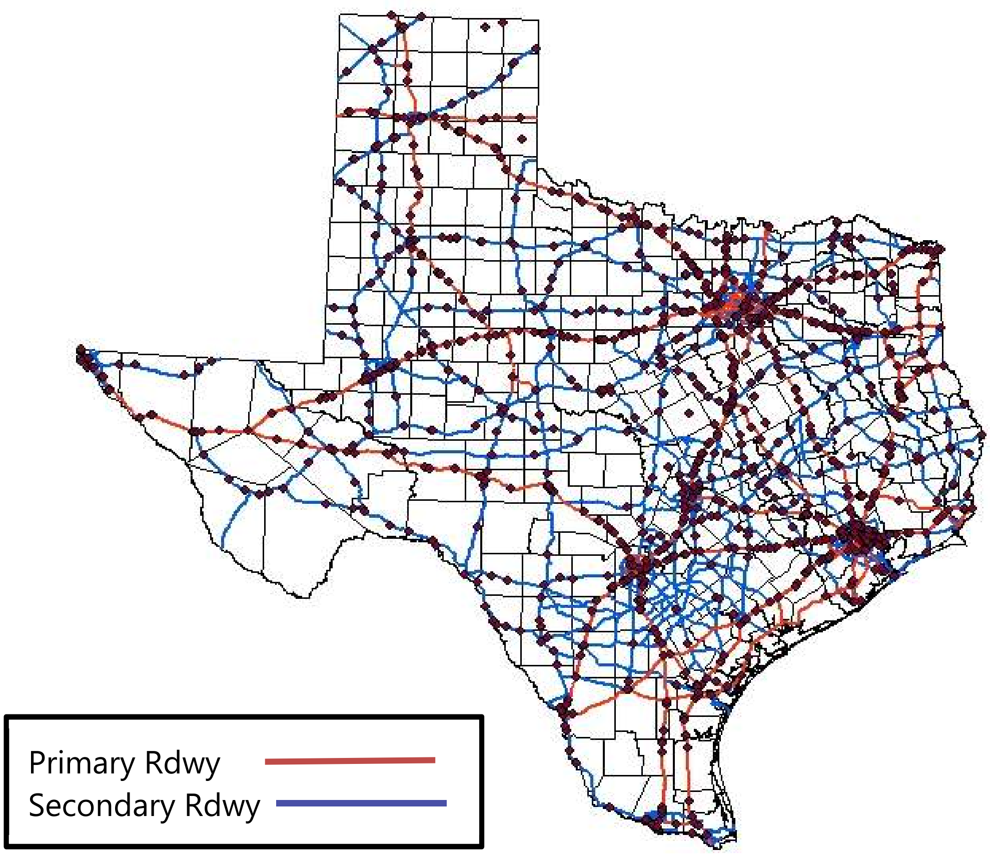


Figure 8. Map Showing Different Hotelling Locations in Texas.

SUMMARY OF FINDINGS

Table 10 shows the average number of parking spaces per truck stop by metropolitan planning organization (MPO) boundary. Dallas-Fort Worth, El Paso, Houston, and San Antonio MPOs rank highest in the number of idling locations. Table 10 also shows the average number of parking spaces per truck stop. The Texas border MPOs consisting of the Laredo Urban Transportation Study, South East Texas, Amarillo, and El Paso have the highest number of average parking spaces per location with 112, 101, 99, and 96, respectively.

Table 10. Number of Idling Locations by Metropolitan Areas.

MPO Name	No of Idling Locations	Average Space per Location
Laredo Urban Transportation Study	9	112
South East Texas	8	101
Amarillo	10	99
El Paso	15	96
Lubbock	7	61
Abilene	5	55
Alamo Area	42	54
Waco	17	51
Sherman-Denison	1	48
Permian Basin	18	47
Hidalgo County	13	43
North Central Texas	110	41
Wichita Falls	5	40
Killeen-Temple	7	39
Longview	4	39
Houston-Galveston Area Council	123	38
Tyler	10	28
Victoria	7	27
Texarkana	5	25
Bryan-College Station	3	22
Corpus Christi	2	21
Harlingen-San Benito	5	20
Capital Area	39	14
San Angelo	3	11
Brownsville	1	6
None	448	30

Vehicle Probe Data

TTI investigated the application of vehicle probe data in characterizing the Hotelling idling behavior. TTI obtained samples of vehicle probe data from two sources:

- American Transportation Research Institute (ATRI); and
- INRIX.

The main feature of these datasets is their large size and fine resolution, which includes location, time, and speed information for each vehicle in the sample. It must be noted that the ATRI and INRIX data do not have any information on whether the engine is on or not. Because of this characteristic of these data sources, traditional data processing and analysis tools cannot be used to process and analyze the data. TTI staff used a combination of database systems, business intelligence systems, programming, and GIS to process and extract information related to these datasets. This chapter documents TTI's efforts using the INRIX and ATRI dataset.

American Transportation Research Institute (ATRI)

ATRI, part of the American Trucking Associations (ATA) Federation, is a 501(c) (3) not-for-profit research organization headquartered in Arlington, VA. ATRI collects GPS-based, spatial, and temporal information for a large sample of trucks with onboard, wireless communication systems in the U.S. This data is used by planning agencies to improve freight planning and safety. This data includes geospatial (coordinates) and temporal (time/date stamp) information for the corresponding trucks. Currently, more than 100 million GPS data points are collected per day by ATRI.

For this study, TTI purchased a sample of ATRI waypoint data; i.e., coordinates and time stamps of all trucks in the target areas. Waypoints refer to movement of individual vehicles at a relatively fine temporal resolution, usually between 30 seconds and 10 minutes.

Table 11 shows the temporal and spatial scale of ATRI data purchased for this study. The data sample was from four months each containing waypoints from nine consecutive days. Figure 9 show a sample of the ATRI data used in this study and Figure 10 shows the coverage in Dallas, El Paso and Harris counties.

Table 11. Temporal and Spatial Scale of ATRI Data Used in this Study.

Data Type	Temporal scale	Spatial Scale (Counties)
Waypoints	3rd - 11th December 2016 22nd - 30th July 2017 17th - 25th June 2017 4th - 12th March 2017	Harris Dallas El Paso

TruckID	Date	Time	Latitude	Longitude	Speed (mph)
1076443	*Tuesday, July 25, 2017*	*12:00:00 AM*	*29.7680884*	*-95.1464985*	*0*
1076443	*Tuesday, July 25, 2017*	*12:00:10 AM*	*29.7680884*	*-95.1464985*	*0*
1076443	*Tuesday, July 25, 2017*	*12:15:00 AM*	*29.7680884*	*-95.1464985*	*0*
1076443	*Tuesday, July 25, 2017*	*12:30:00 AM*	*29.7680884*	*-95.1464985*	*0*
1076443	*Tuesday, July 25, 2017*	*12:30:10 AM*	*29.7680884*	*-95.1464985*	*0*
1076443	*Tuesday, July 25, 2017*	*12:45:00 AM*	*29.7680884*	*-95.1464985*	*0*
1076443	*Tuesday, July 25, 2017*	*1:00:00 AM*	*29.7680884*	*-95.1464985*	*0*
1076443	*Tuesday, July 25, 2017*	*1:00:12 AM*	*29.7680884*	*-95.1464985*	*0*
1076443	*Tuesday, July 25, 2017*	*1:15:00 AM*	*29.7680884*	*-95.1464985*	*0*
1076443	*Tuesday, July 25, 2017*	*1:30:00 AM*	*29.7680884*	*-95.1464985*	*0*

Figure 9. ATRI Waypoint Data Sample.

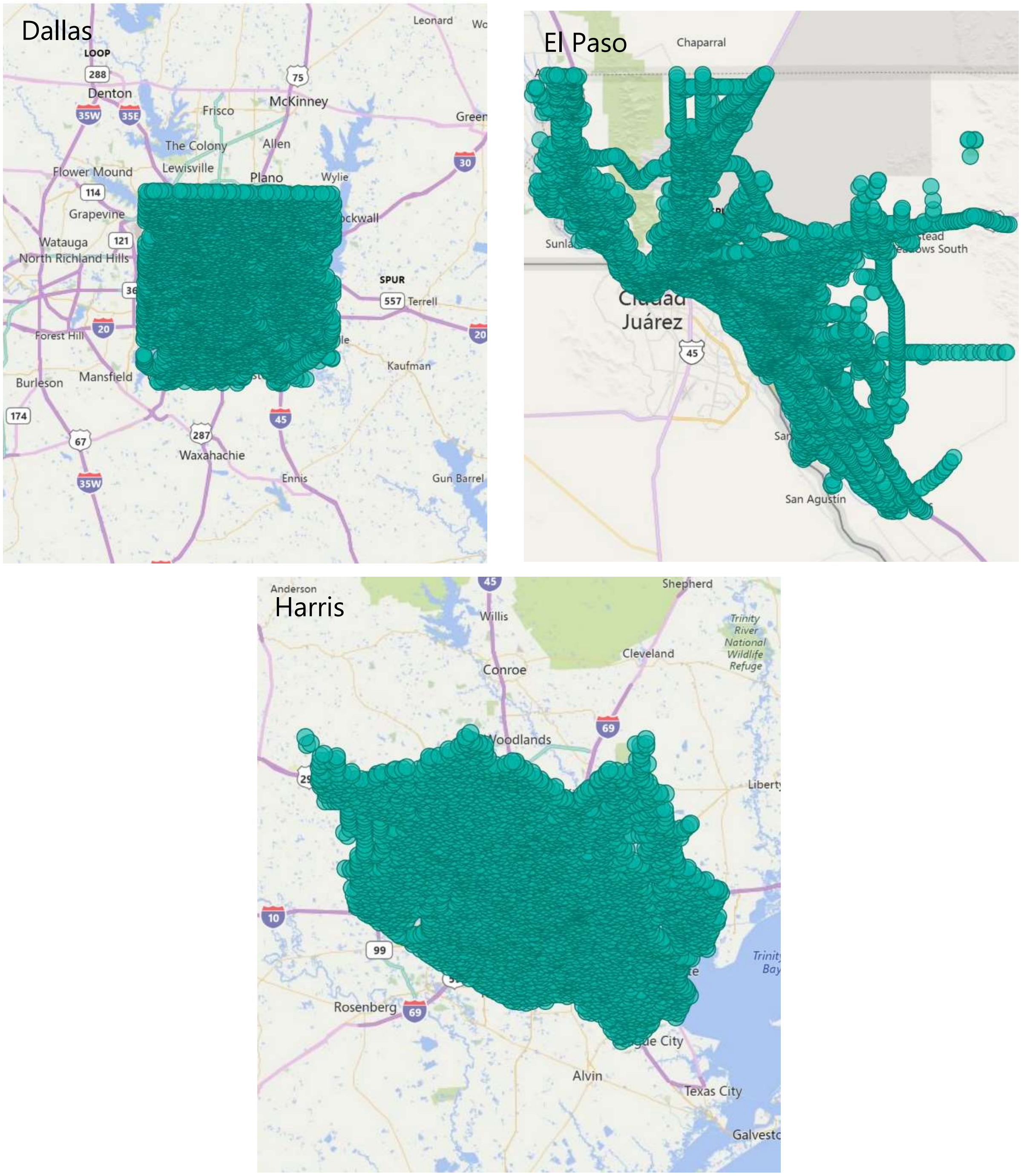


Figure 10. ATRI Data Coverage in Dallas, El Paso and Harris Counties.

INRIX

INRIX collects real-time anonymous data from mobile phones, connected cars, trucks, delivery vans, and other fleet vehicles equipped with GPS locator devices. Data is provided as raw data, processed data, and/or as shape files. Roadway location is referenced to the traffic management canter (TMC). Data are processed to provide travel time, time-cost delays, trends maps and charts, bottleneck and incident data, and can provide the underlying anonymized historical data for downloading. The data collected is processed in real-time 24 hours a day, creating traffic speed information for major freeways, highways, and arterials across North America.

Table 12 shows the spatial and temporal scale of INRIX data used for the study. TTI staff used a sample of INRIX trip data covering a period of 45 consecutive days. The INRIX trip database consists of post processed trip data, which identifies start and end points and times of each trip including non-moving trips (i.e., when a truck is stopped). The INRIX dataset contained both truck and non-truck information. Figure 11 shows a partial trip table from INRIX while Figure 12 shows INRIX data coverage in Bexar County, TX.

Table 12. Temporal and Spatial Scale of INRIX Data Used in the Study.

Data Type	Temporal scale	Spatial Scale (Counties)
Trip Table	1st September 2017 - 14th October 2017	Bexar Harris

Trip ID	Device ID	Start Date	End Date	Start Latitude	Start Longitude	End Latitude	End Longit
9780f7175e54ac12c12b5762902d9e98	18cd7bc5e5ddad0f2d940281f8f80ebc	*Thursday, September 28, 2017*	*Thursday, September 28, 2017*	*29.785000*	*-95.627200*	*29.785000*	*-95.*
b204976fe717899644759ed18874d587	7d8d58000f504134a3529a2bdfffad49	*Thursday, September 28, 2017*	*Thursday, September 28, 2017*	*29.627300*	*-95.245300*	*29.627300*	*-95.*
deb02f259b1cb99a8b6074df4f117aca	72136b74c251e9504af8ef9fea666852	*Thursday, September 28, 2017*	*Thursday, September 28, 2017*	*29.864500*	*-95.405200*	*29.864500*	*-95.*
090e1565db8c6f2d5cf09c7c01290494	e493229f8825b49982f18a762ce3e044	*Thursday, September 28, 2017*	*Thursday, September 28, 2017*	*29.773600*	*-95.240100*	*29.773600*	*-95.*
9384c35f64b75b1d2030742303b21479	9e3bf226a8bd0dbe68fc06cbc845da6d	*Thursday, September 28, 2017*	*Thursday, September 28, 2017*	*30.017700*	*-95.426000*	*30.017700*	*-95.*
1c68fcf011c44068274638352935 69da	040de92edfe038c46bdaa86a8618293a	*Thursday, September 28, 2017*	*Thursday, September 28, 2017*	*29.945400*	*-95.416000*	*29.945400*	*-95.*

Figure 11. Partial Trip Table from INRIX.

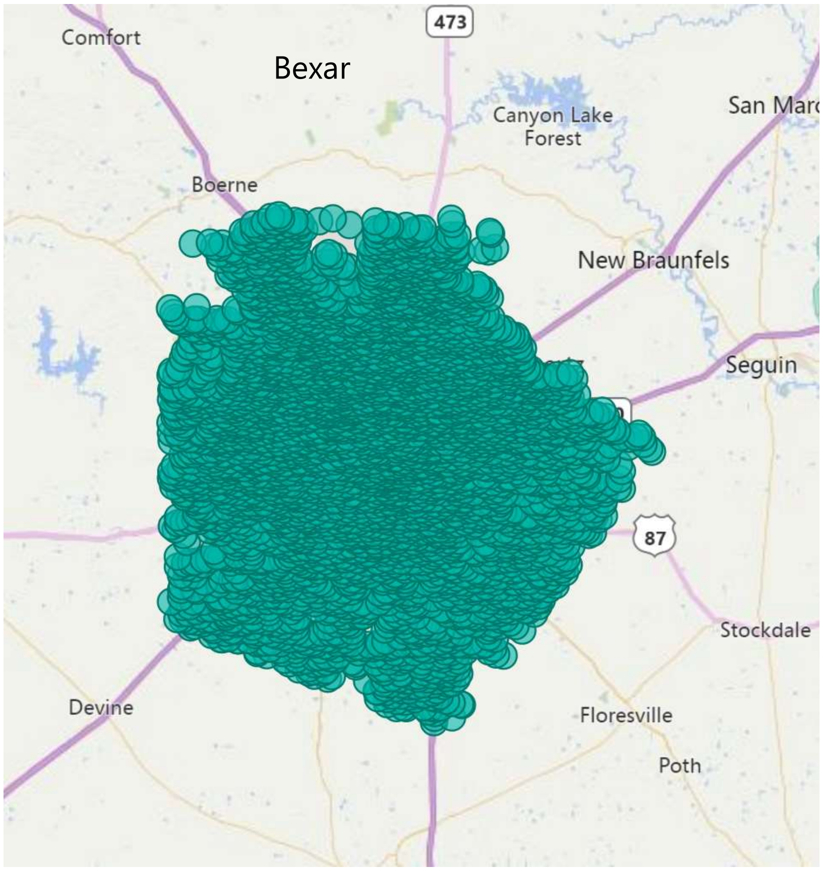


Figure 12. INRIX Data Coverage in Bexar County.

Data Processing And Analysis

ATRI and INRIX data was verified and processed to identify how many hours and where trucks were stopped by superimposing Hotelling facility GIS layer files from the previous chapter. ATRI and INRIX have stated that their samples consist of approximately 8-10% of the active on-road truck population; although the sample size varies by time and location. The vehicle activity data was cleaned to extract idling activity parameters. The following flowchart (Figure 13) describes how TTI extracted idling activity from these datasets.

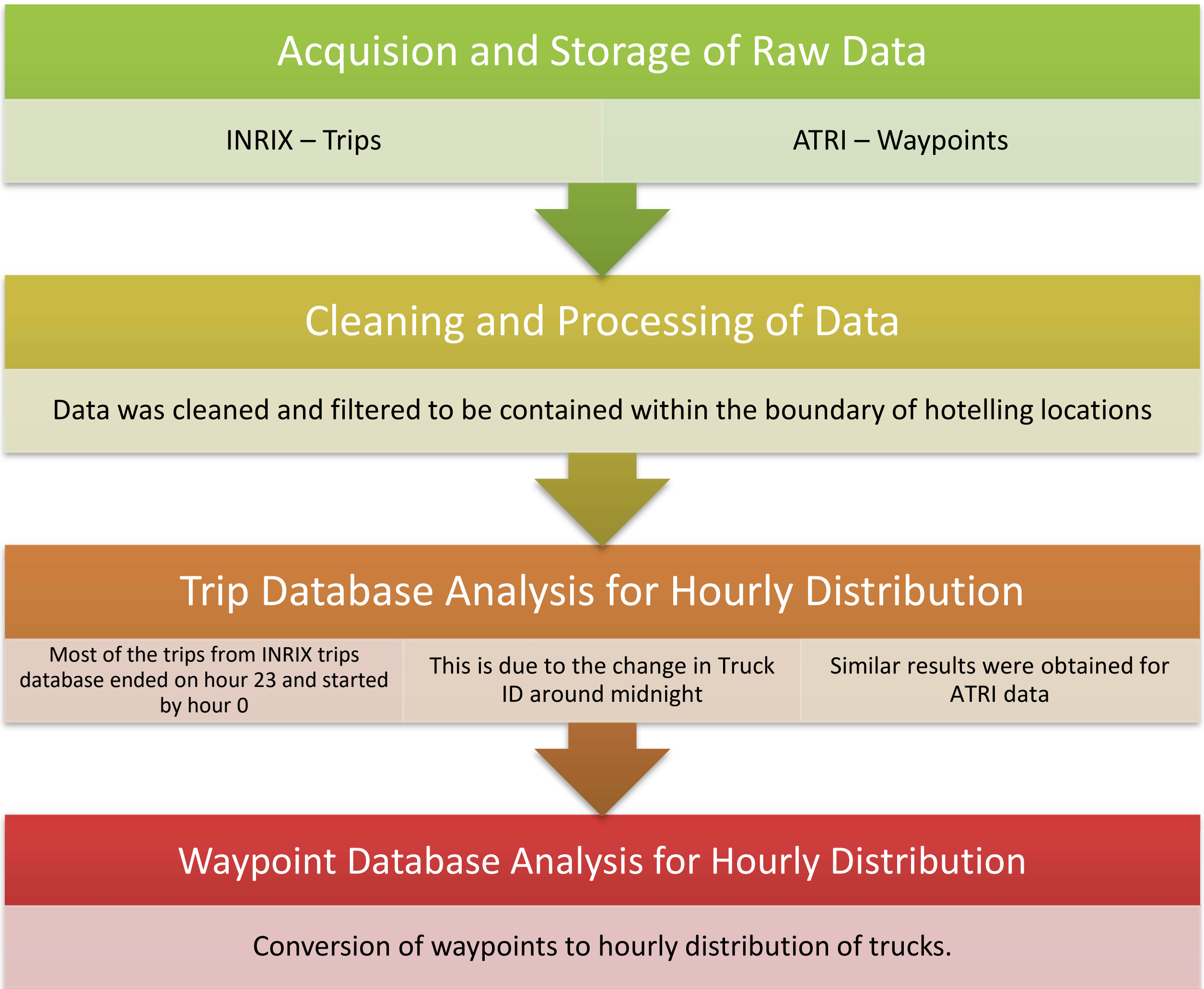


Figure 13. Framework for Data Analysis of INRIX and ATRI Data.

Acquisition and Storage of Raw Data

ATRI raw data was saved as a SQL Server database. The raw data was reviewed for null values and the rows that had null values in any of the fields were removed. Table 13 shows the database structure. The total number of rows in the raw ATRI waypoints database is 227,842,271.

Table 13. Description of the ATRI Waypoints Database.

Variable name	Date type
Date	The capture date and time of the waypoint
Latitude	The latitude coordinates of current position
Longitude	The longitude coordinates of current position
Speed	Spot speed of the vehicle in mph
TruckID	A trucks' unique identifier

Similar to ATRI, INRIX trip summary data was also setup as a SQL Server database and the rows that had null values in any of the fields were removed. The INRIX dataset included light-, medium-, and heavy-duty vehicles. Table 14 shows the database structure for INRIX trip summary data. The total number of rows in the INRIX trip database is 675,000.

Table 14. Description of the INRIX Trips Database.

Variable Name	Description
TripID	A trip's unique identifier
DeviceID	A device's unique identifier
ProviderID	A provider's unique identifier
StartDate	The trip's start date and time in UTC, ISO-8601 format
EndDate	The trip's end date and time in UTC, ISO-8601 format
StartLocLat	The latitude coordinates of the trip's start point in decimal degrees
StartLocLon	The longitude coordinates of the trip's start point in decimal degrees
EndLocLat	The latitude coordinates of the trip's end point in decimal degrees
EndLocLon	Longitude coordinates of the trip's end point in decimal degree
VehicleWeightClass	Numeral representing the vehicle weight class 3 – for HDV
MovementType	1 = Moving Trip, 0 = Non-Moving Trip (i.e., Stopping)

Cleaning and Processing of Raw Data

Both INRIX and ATRI data were imported into Microsoft PowerBI® for further cleaning and processing. In the case of INRIX trip data, only truck trips were imported into Power BI. The main goal of this step was to minimize the size of the data for performing further analysis. The Hotelling locations database was also imported into PowerBI®. The waypoint and trip summary data were filtered by a circular buffer of 400 m around each idling location. Figure 14 shows an example demonstrating the results of this step. Using this step, the row count of the ATRI data was reduced from approximately 270 million records to 42.6 million records.

The filtered waypoints data were then imported into ArcGIS®. TTI staff created polygons representing the exact boundary of the Hotelling locations for all the identified facilities in the counties included in the ATRI dataset. Geofencing was done by using ArcGIS® Spatial join function to extract only the waypoints located within the boundaries of the identified facilities. This step reduced the size of the waypoint table to approximately 6.8 million records. Figure 15 shows the waypoints filtered inside facility T102.

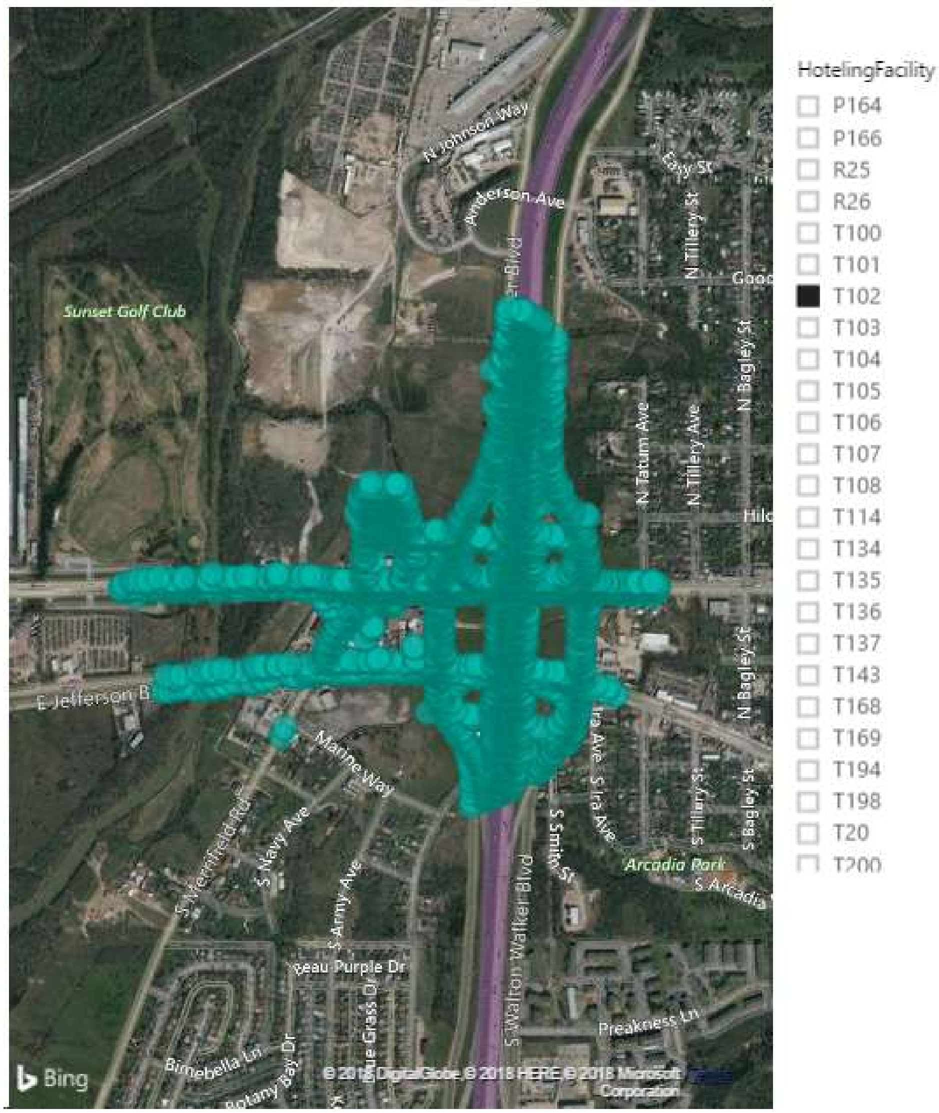


Figure 14. Filtered Waypoints with a Circular Buffer of 400m around Hotelling Facility T102.

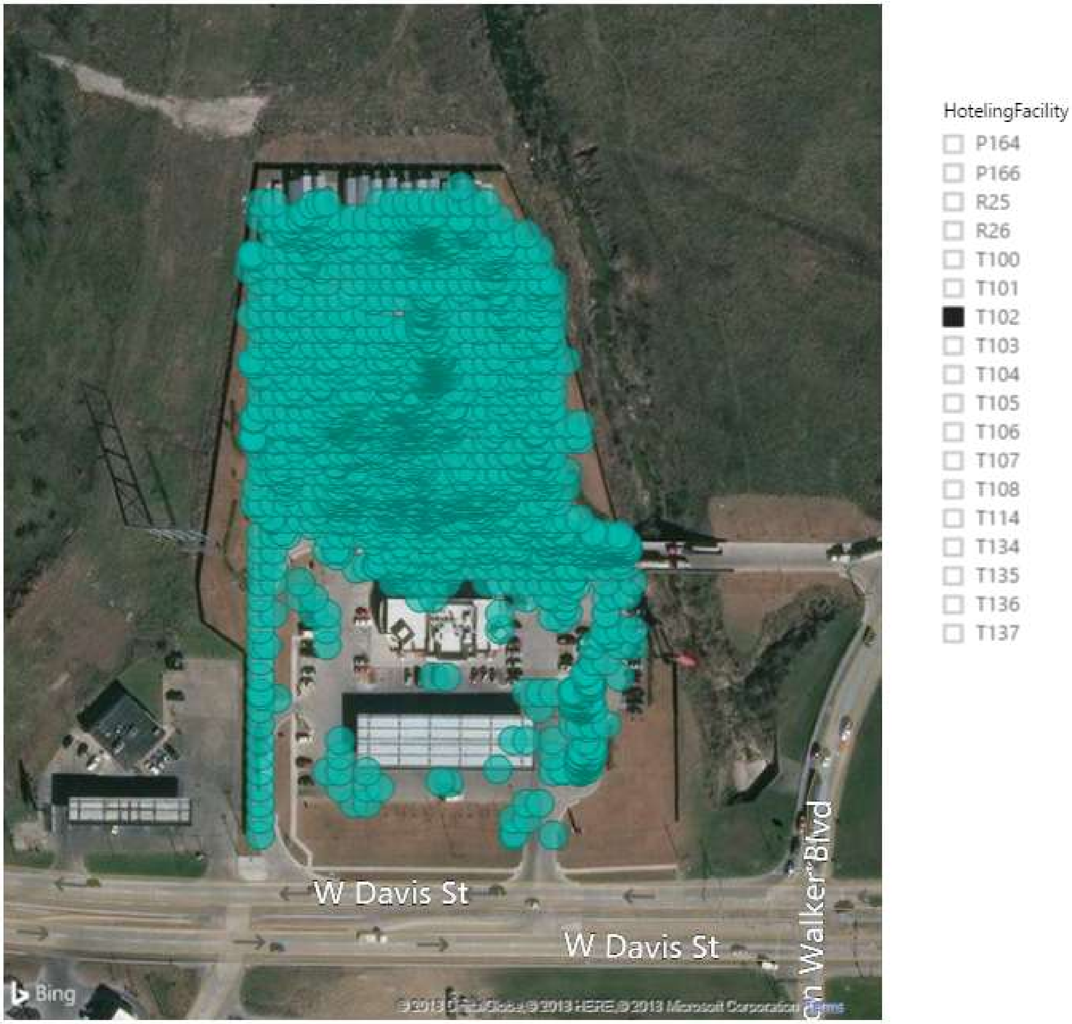


Figure 15. Filtered Waypoints with Polygons Representing the Exact Boundary around Hotelling Facility T102.

Trip-Based Analysis

The geofenced data extracted from ArcGIS® was imported into Power BI and analyzed to extract idling behavior parameters. The first step involved identifying and extracting the non-movement trips (i.e., a period that a truck is stopped) from the waypoint observations. The INRIX dataset had already been processed by INRIX and included the trip information the start and end time stamps and coordinates. Figure 16 shows the non-movement trips (i.e., stops) identified from ATRI data at Hotelling location 102.

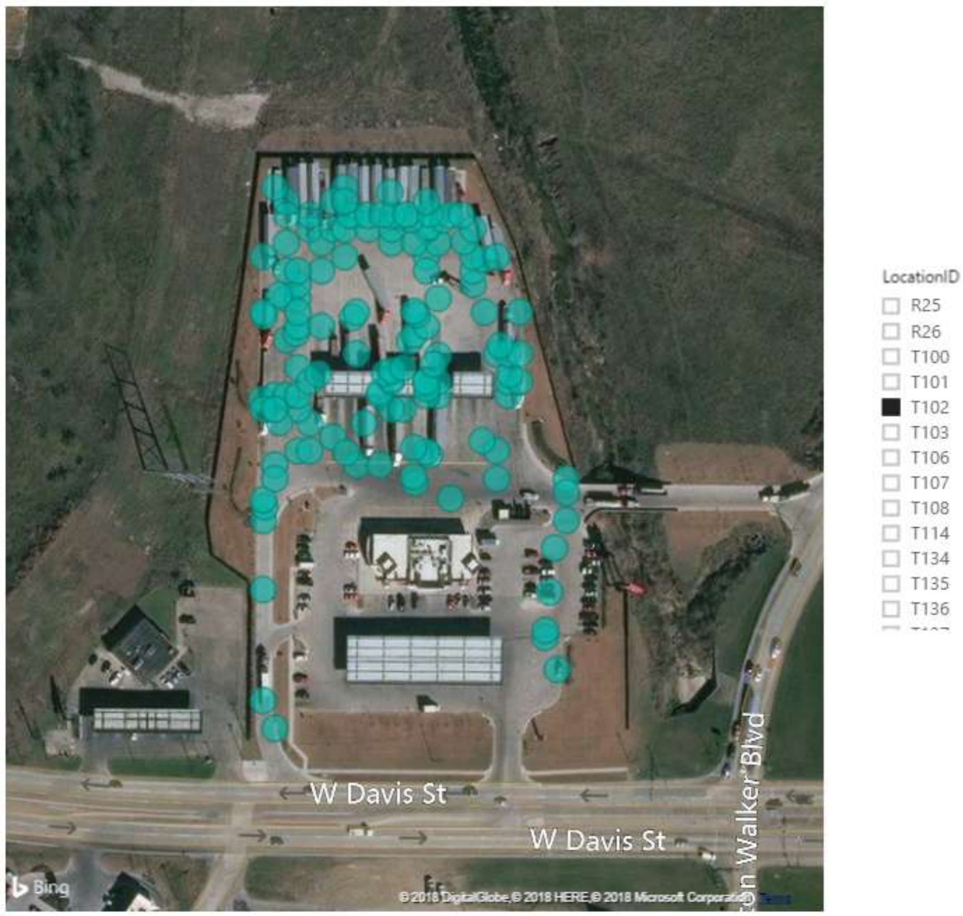


Figure 16. Trips Identified at Hotelling Facility T102 Represented by Start Positon.

TTI staff extracted the duration, start time, and end time of each valid non-movement trip from the resulted trip tables. Minimum and maximum stop durations of 4 and 14 hours were used to filter the most likely hotelling non-moving trips. Researchers then prepared summary tables and graphs showing the distribution of number of starts and trip/stop by the start and end time. Figure 17 shows the hourly distribution of the number of trips by start hour. Figure 18 shows the distribution of average hotelling stop duration by the start hour. As shown in Figure 17, hourly distribution of the number of trips by trip start hour and end hour shows a large peak for trips ending at Hour 23 and starting at Hour 0. Additionally, in Figure 18 there is no hotelling stop duration shown for hours after 19:00. The reason for this trend was explored and it was found that both ATRI and INRIX have the practice of changing the truck ID of a substantial portion of the trucks in their samples around midnight due to data privacy concerns.

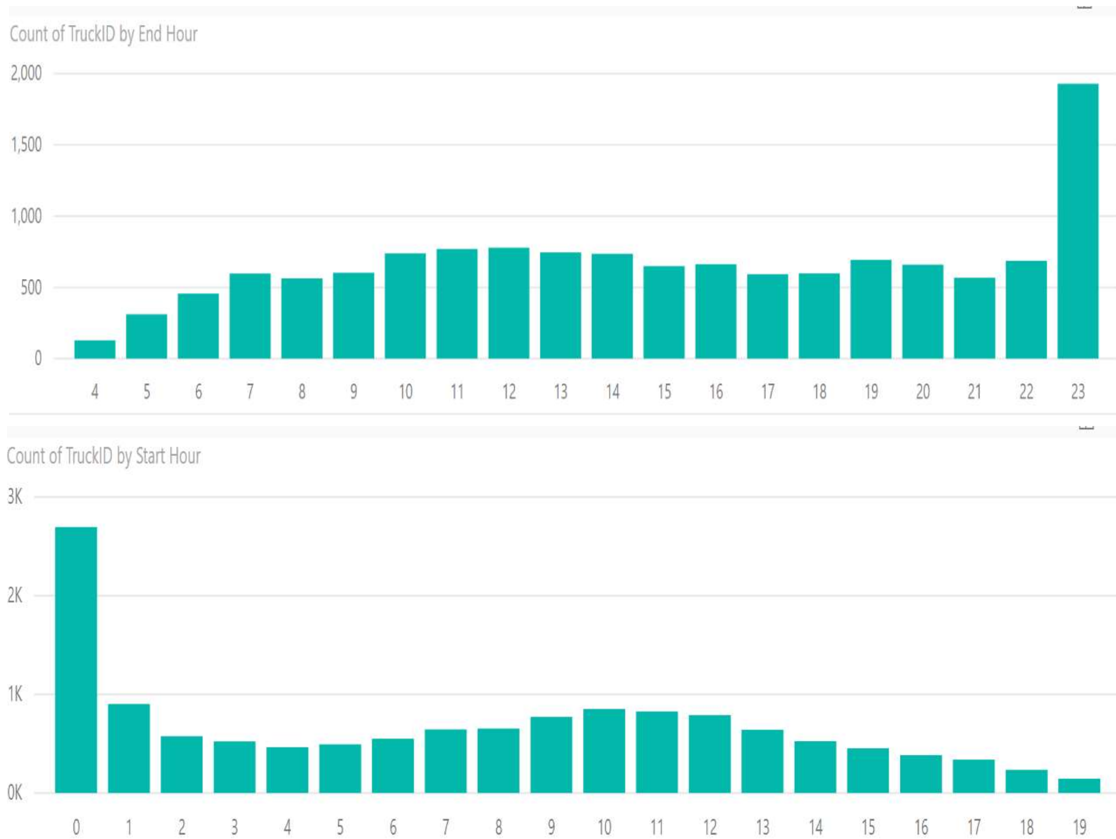


Figure 17. Distribution of Number of Hotelling Stops by Start and End Hour.

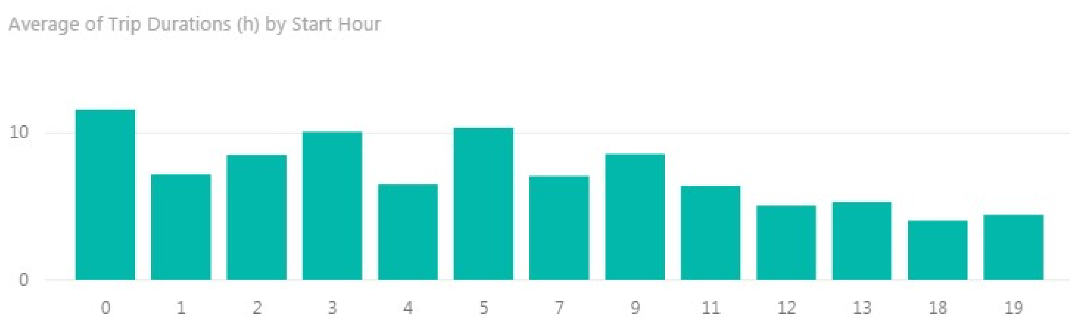


Figure 18. Distribution of Hotelling Stops Durations by Start Hour.

The change of a truck's ID results in many non-movement trips being broken into two disjointed pieces without any parameters connecting them directly. The split of the non-movement trips results in the following flaws:

1. A valid potential hoteling stop with a duration of more than 4 hours but less than 8 hours might be flagged as invalid stop.
2. An invalid hoteling stop with a duration of more than 14 hours might be flagged as two valid hoteling stops.

These two flaws result in inaccuracy of the hoteling stops' durations which will invalidate the distribution of hoteling duration, stops' start time, and end time. These distributions are needed to characterize the sample population's hoteling behavior. When combined with appropriates methods for estimating idling proportions and arrival of long-haul trucks at the facility, one could built a robust estimation of the hours of idling that more realistically captures the actual extended idling behavior.

TTI staff investigated the possibility of a solution to this limitation. When a truck's stop is split into two pieces and there are multiple trucks present at the same location, each non-movement trip ending at hour 23 will have multiple potential matches from stops that start after hour 0. To find the best match, probabilistic methods are needed to use other criteria such as location proximity and expected stop durations can to be employed to find the best match.

Developing and validating such methods for a large amount of data included in the ATRI and INRIX datasets would require an unforeseen amount of time and resources as well as the involvement of the data provider (to confirm and validate the assumptions as well as access to other potentially available parameters in their raw data). The team therefore concluded that the technical and financial resources needed for overcoming the trip split limitation are beyond this study and decided not to use the trip-based analysis in this study. Instead, TTI researchers used the ATRI waypoint data to extract the hourly number of stopped trucks as described in the following section.

Hourly Distribution of Number of Trucks

The geofenced ATRI waypoints data were processed to obtain the number of trucks present inside each facility for a given hour of the day. Minimum stop durations of 45 minutes in each hour were used to extract this information. The hourly number of stops was normalized using the total number of trucks present at each facility for 24 hours to establish the hourly distribution of trucks. Because of the relatively small size of the dataset, the individual facilities showed a large level of noise and did not always show a consistent trend. To address this limitation, the hourly distributions were aggregated to the county level. Figure 19 shows the hourly distribution of the number of trucks for different seasons and counties. As discussed in the data analysis chapter, these results were used in validating the assumption of Hotelling idling estimation methodology that TTI developed in this study.

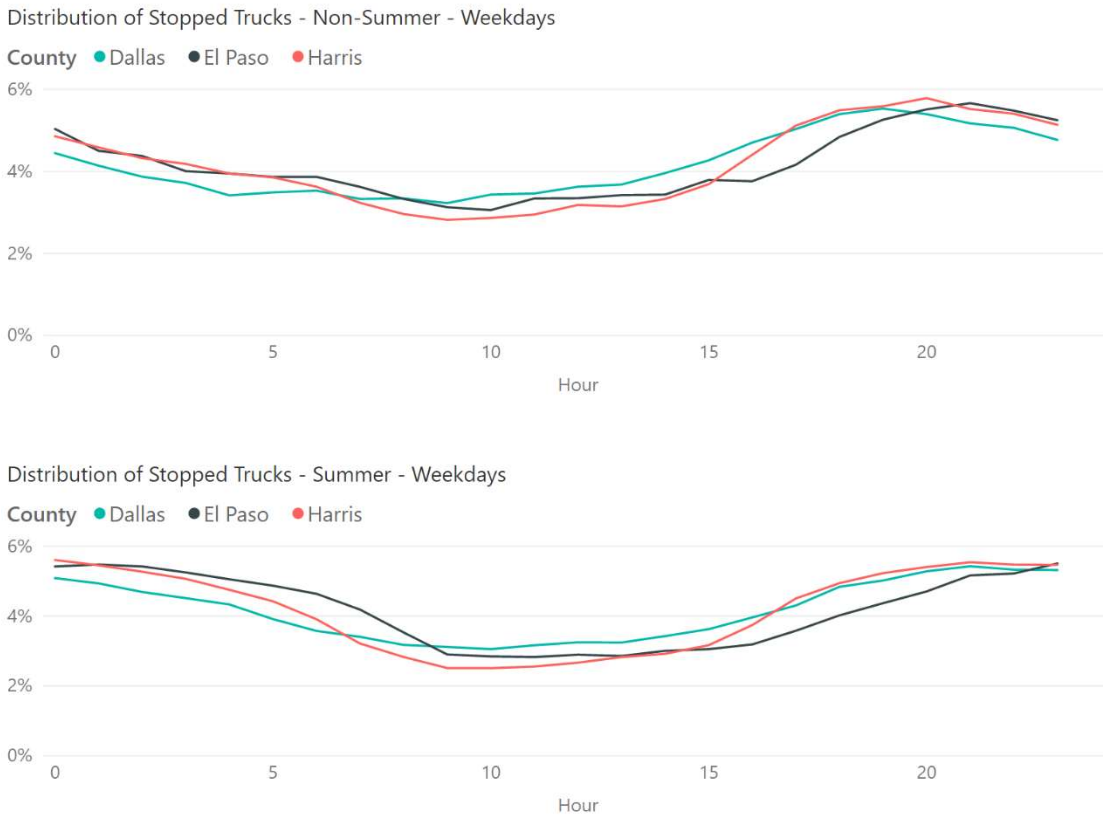


Figure 19. Hourly Distribution of Stopped Trucks by County.

Further Potential of Emerging Data Sources

Although the disjointed trips limitation of the ATRI and INRIX prevented the TTI staff from using a trip-based analysis in this study, the team still recognizes the potential value in such analysis if the disjointed trip limitation is addressed and solved. A trip-based analysis using corrected data could reveal a great amount of information on the idling behavior of the long-haul trucks. Specifically, such analysis could build a detailed profile of potential hotelling stops by time-of-day, facility type and size, etc. The current methodology for estimating the extended idling of long-haul trucks is based on a limited number of snapshot observations from a sample of locations. These field observations are combined with appropriate assumptions and analyzed to extract the key parameters and build a behavioral model that approximates the sample populations' behavior based on those parameters.

Essentially, the current method uses discrete and aggregate observations (i.e. hourly number of stopped idling trucks) to build a predictive model of a continuous behavior (i.e. extended idling of a truck). Direct field observations are labor intensive, time consuming, costly, and often the limiting factor in terms of the scope of the data requirement. Direct observation of individual trucks' idling behavior over time (e.g. seasons) and space (e.g. different regions) is cost prohibitive and practically impossible. Using emerging datasets such as ATRI and INRIX, one can theoretically track the driving and hotelling (i.e. extended stops) behavior of thousands of trucks at a large number of locations and for an extended period of time.

In addition to the vehicle probe data such as ATRI and INRIX, a new source of data in the form of engine activity information from Electronic Logging Devices (ELDs) is emerging that can revolutionize the extraction of truck idling behavior at a very detailed level. The FMCSA has mandated the use of ELDs for compliance with the HOS requirements for long-haul truck drivers. All motor carriers and drivers subject to the ELD rule mandate must use an ELD after December 18, 2017.

ELD rule requirements state that an ELD must connect to the truck's engine and record if the truck is in motion. Many ELDs record whether the engine is on or off. Since the ELD rule requirements are applied to virtually all long-haul trucks newer than model year 2000, it has created a potential truck activity data source with an unprecedented large sample size and detailed information about the trucks and their activities. When combined with trip-based results from vehicle probe data, the ELD data can be used to build an idling behavior profile at a very detailed level.

Data Collection

The data collection activities described in this chapter were conducted to quantify extended idling and APU usage for long-haul heavy trucks in Texas. Data collection was conducted using two approaches: direct observation of long-haul truck idling activities during Hotelling; and oral surveys of long-haul truck drivers regarding their use of APU and idle reduction technology during Hotelling. A description of each of these data collection activities is provided in the following sections.

Truck Idling Data Collection Activities

During the field data collection, the research team followed a set protocol each time they collected data. The protocol was established to ensure that the data from each collection effort was accurate and the same data was collected each time the team visited a truck stop location. This section details the protocol that was established and followed during the field data collection efforts.

The goal of each data collection effort was to gather a count of the idling and non-idling trucks at a given time. This was accomplished by using a team of two researchers for each data collection effort. All data collection efforts were conducted by having a vehicle drive slowly through the rows of parked trucks. While one researcher drove past the trucks, the other researcher would observe and record the data. To ensure that the collected data was accurate, TTI collected the data using two methods: manually using clickers and electronically using video and audio recording equipment.

Corridor and Location Selection

Field observations were performed along four corridors, each consisting of series of locations where trucks typically stop for extended or overnight rest periods (Hotelling). These locations were either commercial truck stops or highway rest areas. Table 15 and Figure 20 describe the corridors and sites that were used in this study.

Table 15. Corridor and Truck Stop Locations.

Corridor Name	Location	Truck Stop ID - Location Description
I-35 Hillsboro	I-35E from SH 171, Hillsboro, TX to SH 34, Italy, TX	T195 – Hillsboro Loves Travel Stop T197 – Hillsboro TA Travel Center T240 – Italy Loves Travel Stop T241 – Italy Tiger Mart T196 – Carl's Corner (Hillsboro)
I-10 Baytown	I-10 from Thompson Rd to SH 146, Baytown, TX	T26 – Baytown Flying J Travel Plaza T33 – Baytown TA Travel Center T29 – Baytown North Main Mart (Valero) T30 – Baytown Sun Mart (Texaco) T31 – Baytown Conoco Travel Plaza T28 – Baytown Express Travel Plaza (Chevron) T32 – Baytown Loves Travel Stop
I-35 Jarrell/Belton	I-35 from Ronald Reagan Blvd, Jarrell, TX to US 190, Belton, TX	R3 – TxDOT Bell County Safety Rest Area (SB) T245 – Jarrell Star Station (Shell/Circle K) T244 – Jarrell Flying J Travel Plaza R2 – TxDOT Bell County Safety Rest Area (NB) T37 – Belton CEFCO Store (Valero) T173 – Georgetown Sunmart*
I-10 East San Antonio	I-10 from Ackerman Rd to N Foster Rd, San Antonio, TX	T393 - San Antonio Petro Center T396 – San Antonio TA Travel Center T388 – San Antonio Flying J Travel Plaza T395 – San Antonio Pilot Travel Center T90 – Converse Sunmart* T295 – Marion Exxon Truck Stop *

* Location removed from survey after one event.

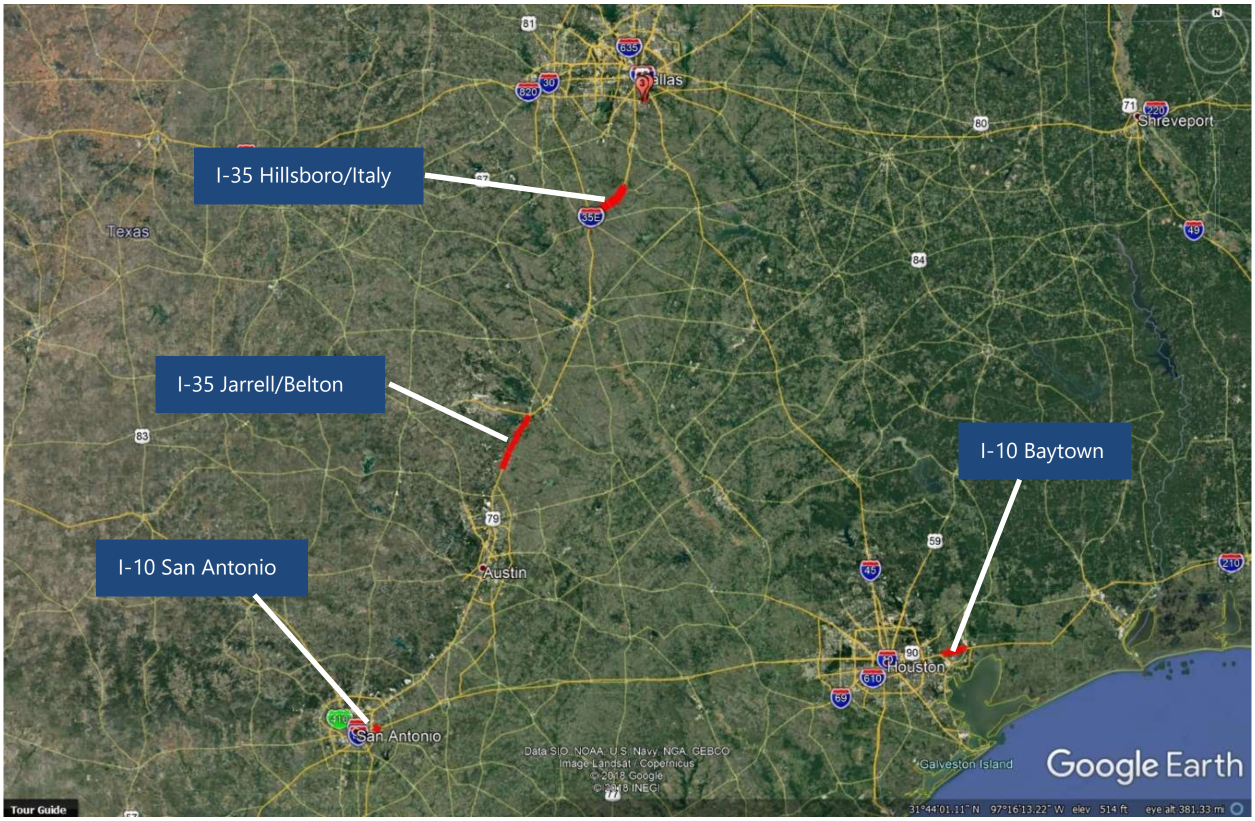


Figure 20. Data Collection Corridor Locations.

The corridors for this survey were selected to represent various areas of the state. The study team searched for corridors where there is an occurrence of multiple truck stop facilities relatively close together to allow for efficient survey activities without subjecting the survey team to unsafe nighttime working. The number of truck stop locations along each corridor was selected to allow researchers to survey all the selected locations within the corridor (i.e., one round of surveys) in approximately one hour. Depending on the time-of-day, one round of surveys ranged from 31 minutes to one hour and 37 minutes. The average duration of a survey round for the project was 55 minutes.

Equipment

The electronic data collection was conducted using the following equipment:

- Visual data:
  - Samsung Galaxy Tab S3 Android Tablet
  - FLIR ONE Pro Thermal Imaging Camera
- Audio data
  - Technica AT8015 Shotgun Microphone

The FLIR ONE Pro camera included software that ran on the Galaxy Tab tablet. To collect the video data, the research team would hold the microphone on the door, facing out the window toward the parked trucks. The thermal imaging camera would then be held just outside the passenger side door, facing outward, with the window rolled down. To collect the data, the researcher driving the team vehicle would drive approximately 5-10 feet in from of the rows of parked trucks. This allowed the thermal camera and microphone to capture the hoods of the trucks as they were parked. The video would be recorded for the duration of the time the researchers were driving along the rows of trucks. The captured video, by combining the thermal image of the hood of the trucks and the audio from the directional microphone, would allow the researchers to watch the video later and verify the manual counts. Figure 21 shows the tablet, thermal camera, and microphone. Figure 22 shows the set-up for data collection. The thermal image cameras were set such that no personal identifying data, including the truck license plate, were recorded.

Informational letters with background and project contact information regarding the APU survey activities were prepared for each location where the APU survey was to be conducted (Appendix B). APU survey team members carried copies of these letters during survey activities and provided letters to any interested person contacted by the survey team.

Figure 21. Equipment for Electronic Recording.

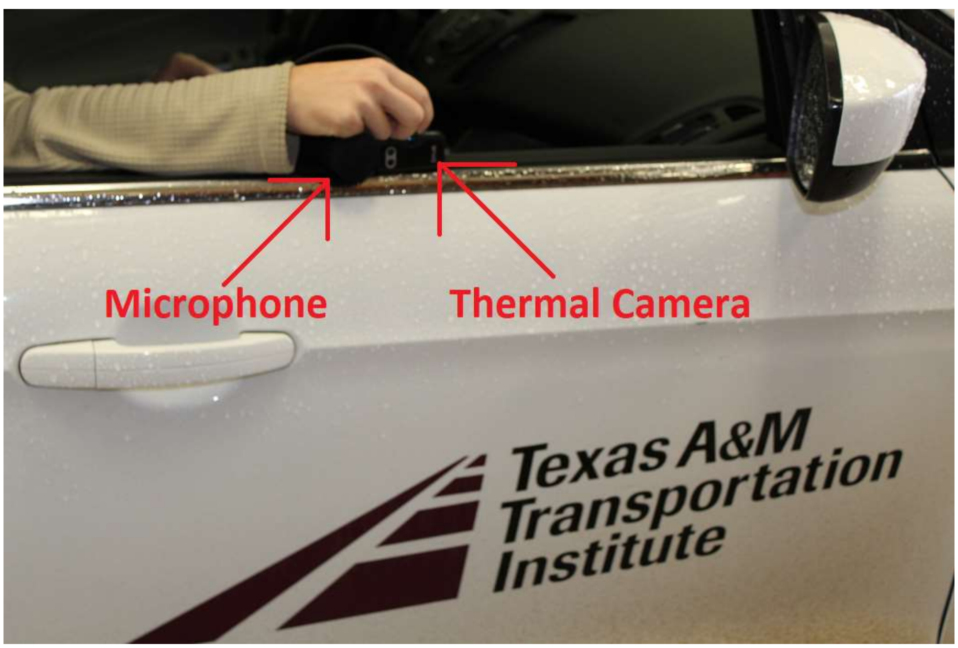


Figure 22. Setup for Electronic Recording.

Selection of Data Collection Equipment

To collect the field data on idling trucks at truck stops, the research team examined different technologies that would assist in accomplishing the task and ensuring the quality of the observations. The focus of the technology selection was to find a tool that would assist the researchers in gathering the count data for the number of idling trucks at each truck stop.

The first technology that was discussed is a thermal imaging camera. The idea behind using a thermal camera is that the thermal image would be able to pick up the heat signature of an idling truck, and differentiate between one that is idling versus one that is not idling. The team first researched stand-alone cameras. However, no options were found that met all the requirements of recoding video (i.e., not just still images), and also being affordable based on the available budget of the project.

The thermal camera that was selected was the FLIR ONE Pro thermal imaging camera, seen in Figure 23. The FLIR ONE camera has options for use with either an Android or iOS device. For this project the Android unit was selected, and was used in conjunction with a Samsung Galaxy Tab S3 tablet.

Figure 23. FLIR ONE Pro Camera (Image from flir.com).

After obtaining the FLIR ONE Pro, the research team conducted some testing with the device to determine the best setup of the unit, and to make sure that it would properly identify the trucks that were idling versus those that were not. The FLIR ONE Pro has nine different image settings that vary on how the thermal image is displayed. Figure 24 shows these image settings. The images, while similar, show subtle differences in how the device captures the differences in the hot areas of the image. All the images in Figure 24 were taken of the same truck, within 1 minute of each other, indicating that the temperature changes were minimal during the time the photos were taken. Based on the testing conducted at TTI facilities under controlled testing conditions, it was determined that the setting on the top left was the best to use. However, when trucks were parked close to each other, the heat from one truck would often impact the reading of the truck next to it, as seen in Figure 25.

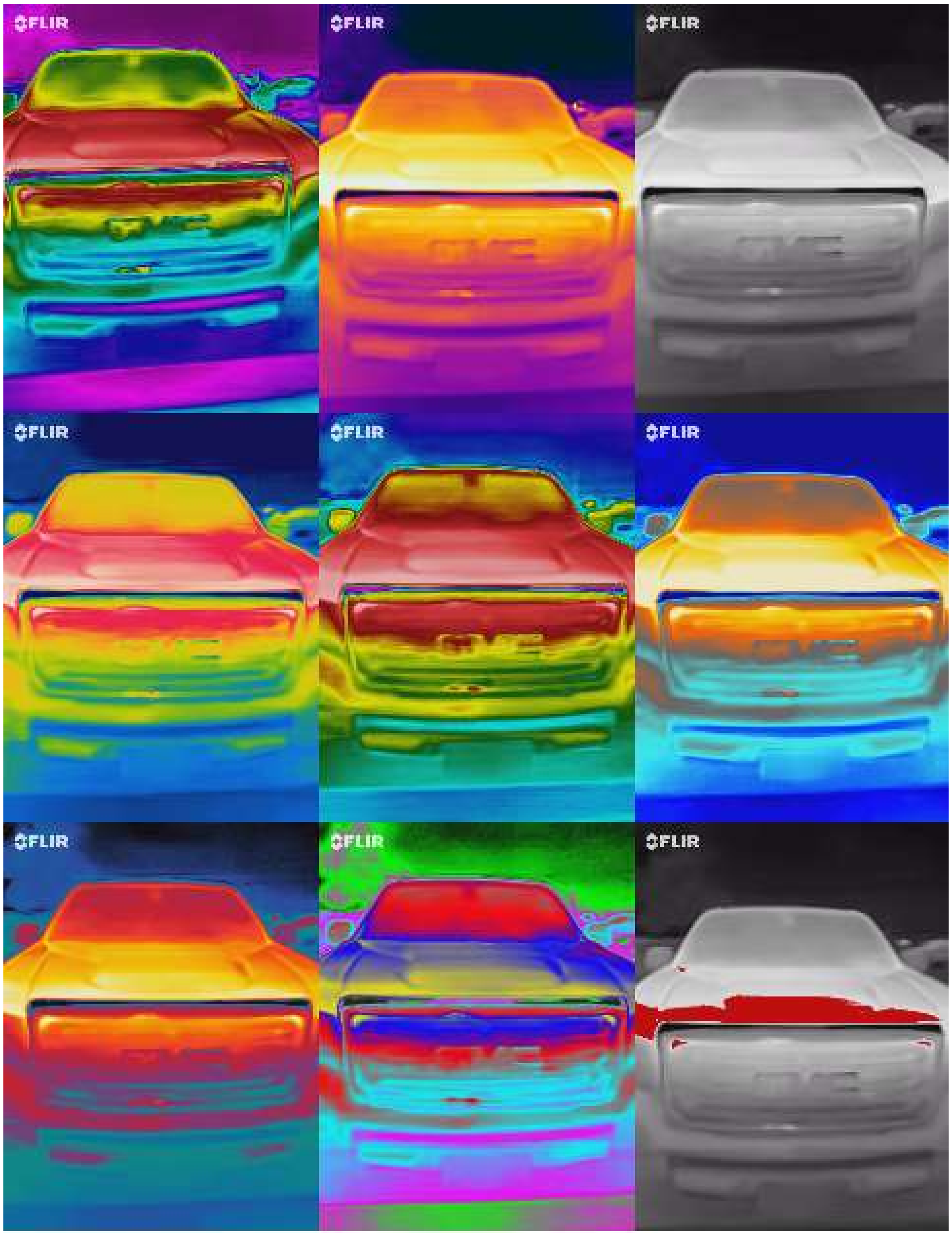


Figure 24. FLIR ONE Pro Image Options.

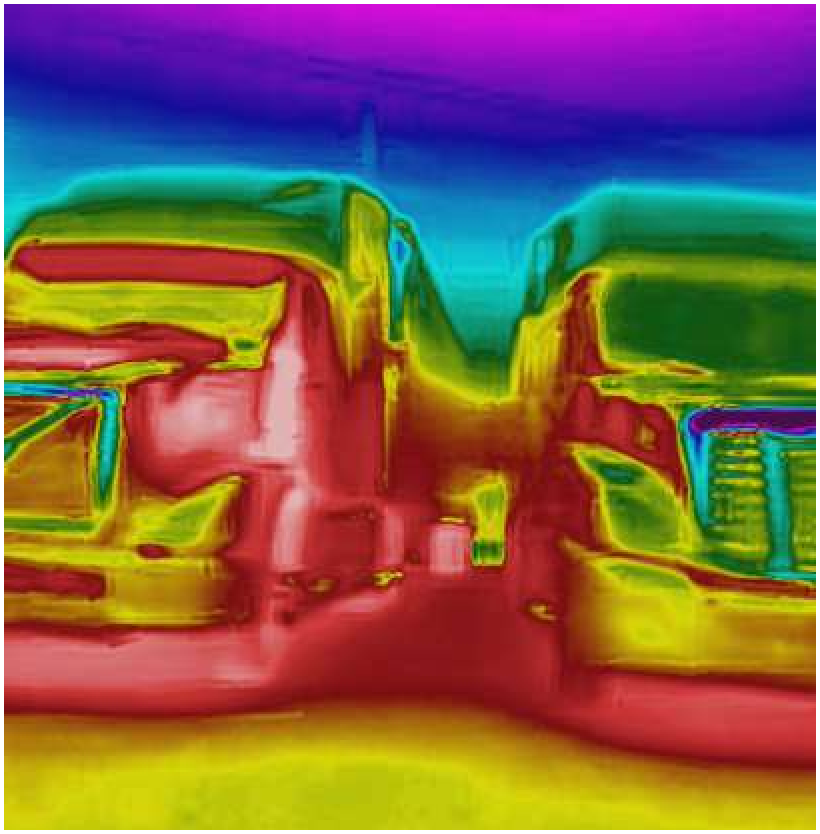


Figure 25. Example of Trucks Parked Side-by-Side.

In Figure 25, the truck to the left is idling, while the truck on the right is not. However, as can be seen in the photo, the heat from the idling truck makes part of the non-idling truck seem to be as hot as the idling truck, and therefore possibly idling. To address this issue, it was determined that an audio recording also be taken during the testing. A shotgun microphone, the Audio-Technica AT8015, was selected for use in the testing. The directional microphone was used with the video to pinpoint which trucks were idling. The combination of sound and video made determining which trucks were idling much easier when the recordings were being analyzed. Figure 26 shows the tablet, camera, and microphone that were used in the testing.

Figure 26. Camera, Tablet, and Microphone for Data Collection.

Data Collection Protocol

Generally, data collection within each corridor was focused on four different time periods within each survey day, surveying each corridor over two 24-hour periods. The time periods covered were:

- Early morning (5-8 a.m.);
- Lunch (11 a.m.-1 p.m.);
- Early afternoon (5-8 p.m.); and
- Late night (11 p.m.-1 a.m.)

During each time period, researchers would begin each survey at a chosen location, usually located on one end of the corridor. The researchers would record the facility name, survey start time, ambient temperature, and then collect and record the data for the facility, then drive to the next facility in the corridor. This continued for each facility in the corridor, and would then repeat. Generally, the teams would complete approximately 2-3 loops during each time period listed previously.

Each data collection effort included a manual count of the idling and non-idling trucks using hand-held clicker counters. As the researchers drove through each truck stop location, they would count each idling and non-idling truck using the clicker counters. Once they had driven through the truck stop location, the counts would be recorded on a data collection sheet with the truck stop location and time-of-day. In addition to the manual counts, electronic data was also collected, using a tablet, thermal camera, and directional microphone. This data was used as a backup data source, so that the researchers could go back, if needed, to verify counts after the data collection was complete.

Data Collection Activities

A total of 21 facilities located in four corridors were surveyed in November and December 2017 using two-person teams. Five I-35 Jarrell/Belton facilities were evaluated a total of 19 times each during the survey conducted on November 27, 28, and 29, 2017. Five I-35 Hillsboro facilities were evaluated 17 times each during December 4, 6, and 8, 2017. Seven I-10 Baytown facilities were evaluated 20 times each during the survey conducted on December 11, 12, and 13, 2017. Four I-10 East San Antonio facilities were evaluated 24 times each during the survey on December 12 and 13, 2017. A total of 419 facility surveys were conducted for this study.

During the first round of data collection activities, survey locations were added or removed based on field observations and travel time to the facilities. If planned survey locations were located too far to allow a round of sampling to be completed in roughly one hour, the survey team discussed and decided whether or not the facility should be included for subsequent surveys. Similarly, if a location or facility that was not initially included in the survey plan was identified to have a reasonable amount of Hotelling activity and could be included in the planned survey without undue burden on survey travel time, the survey team would include the facility for subsequent surveys. Table 16 shows a summary of the truck stop locations and the number of data collection events for each location.

Table 16. Number of Data Collection Events per Location.

Corridor Name	Truck Stop ID - Location Description	Data Collection Events
I-35 Hillsboro	T195 – Hillsboro Loves Travel Stop	17
	T197 – Hillsboro TA Travel Center	17
	T240 – Italy Loves Travel Stop	17
	T241 – Italy Tiger Mart	17
	T196 – Carl's Corner (Hillsboro)	17
I-10 Baytown	T26 – Baytown Flying J Travel Plaza	20
	T33 – Baytown TA Travel Center	20
	T29 – Baytown North Main Mart (Valero)	20
	T30 – Baytown Sun Mart (Texaco)	20
	T31 – Baytown Conoco Travel Plaza	20
	T28 – Baytown Express Travel Plaza (Chevron)	20
	T32 – Baytown Loves Travel Stop	20
I-35 Jarrell/Belton	R3 – TxDOT Bell County Safety Rest Area (SB)	19
	T245 – Jarrell Star Station (Shell/Circle K)	19
	T244 – Jarrell Flying J Travel Plaza	19
	R2 – TxDOT Bell County Safety Rest Area (NB)	19
	T37 – Belton CEFCO Store (Valero)	19
	T173 – Georgetown Sunmart	1
I-10 East San Antonio	T393 – San Antonio Petro Center	24
	T396 – San Antonio TA Travel Center	24
	T388 – San Antonio Flying J Travel Plaza	24
	T395 – San Antonio Pilot Travel Center	24
	T90* – Converse Sunmart	1
	T295* – Marion Exxon Truck Stop	1

*Location removed from survey route following one event.

Technical difficulties with the Android tablet at the beginning of the I-10 Baytown survey prevented use of the thermal imaging camera and microphone for that survey. The Baytown survey was completed using only the clicker counters.

Results of the data collection activities were submitted in a spreadsheet format along with the original technical memorandum. The analysis of the field observation data is discussed in the next chapter.

APU Survey Data Collection Activities

This section details the development and implementation of the APU survey that was conducted as part of the data collection activities for this truck idling project. The goal of the APU survey effort was to obtain information on the type of APU's, if any, that were fitted to a long-haul truck and the individual's use of their APU during typical rest stops. This was accomplished by conducting questionnaire surveys of long-haul truck drivers. The APU survey activities are described in the following sections.

APU Survey Development

The survey was prepared and internally reviewed by TTI's study team. The APU questionnaire was designed to collect facts, not opinion, about truck driver usage of APU's for long-haul truck Hotelling activities.

The proposed APU questionnaire was submitted to Texas A&M University's (TAMU) Internal Review Board (IRB) for review. The IRB determined that "the proposed activity is not research involving human subjects as defined by Department of Health and Human Services (DHHS) and Food and Drug Administration (FDA) regulations,", and the survey could proceed without any additional steps. The APU survey includes 10 questions covering the following topics.

- Type of routes (long-haul or local);
- Make and age of the truck;
- Truck ownership and fleet status;
- Auxiliary power source or idle reduction technology installed on the truck, its typical use, and duration of use; and
- Number of rest stops in a typical day.

The APU survey questionnaire and form are presented in Appendix C of this report.

APU Survey Locations

The survey locations were generally selected from facilities observed in the previously-described truck idling field data collection. Larger facilities were selected for the APU surveys to maximize the potential APU survey responses. The facility managers of each potential survey location were contacted to request permission to conduct the survey prior to survey implementation. Figure 27 illustrates the locations where the APU surveys were conducted.

- Hillsboro Loves Travel Stop (Truck Stop ID T195) Hillsboro, TX.
- Hillsboro TA Travel Center (Truck Stop ID T197), Hillsboro, TX.
- Italy Loves Travel Stop (Truck Stop ID T240), Italy, TX.
- Baytown Flying J Travel Plaza (Truck Stop ID T26), Baytown, TX.
- Dallas Eliza USA (Flying J) Travel Plaza (Truck Stop ID T98), Dallas, TX.

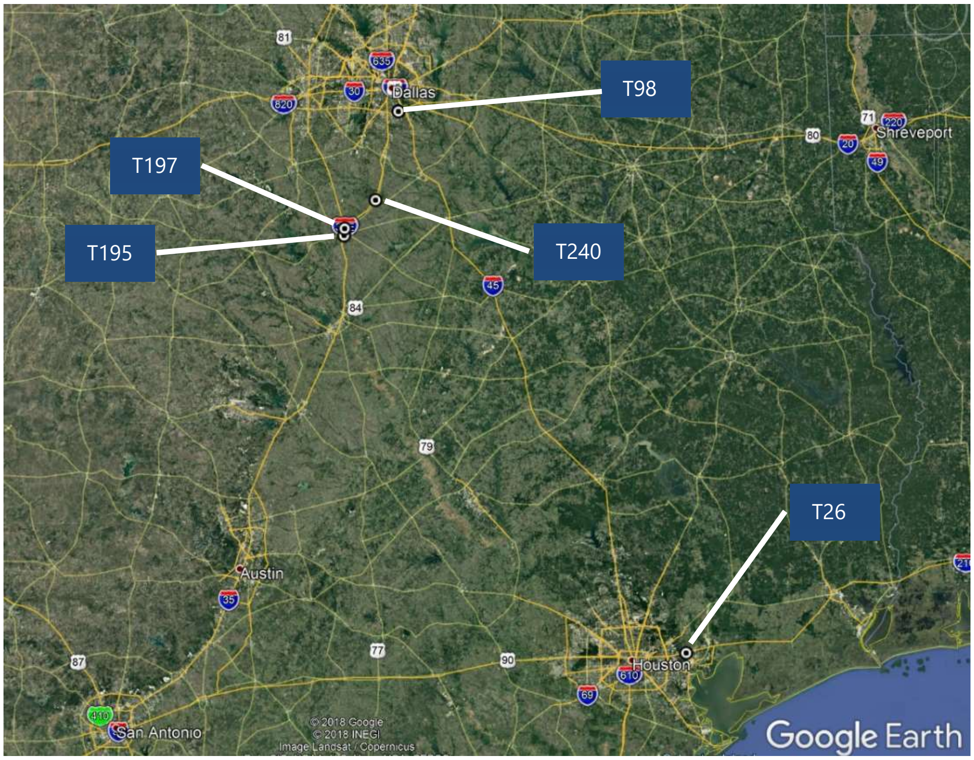


Figure 27. APU Survey Locations.

APU Survey Implementation

The APU surveys were conducted by TTI's two-person study team (interviewers) on December 5, 7, 12, 14, and 15, 2017. Interviewers were stationed at selected truck stops near the entrance to the restaurant/store facilities. Each interviewer was provided with the following equipment:

- Survey forms (Appendix C);
- Questionnaire information sheets (Appendix D);
- Clipboard; and
- Pen or pencil.

For the APU survey questionnaire, drivers were asked whether they will be willing to participate in short, less than five-minute survey regarding their APU usage during rest stops. The interviews were conducted with the study team member reading the questions to willing participants and recording the responses on the APU survey response form.

The APU surveys were conducted on weekdays during the times of day that are highest for driver activity at truck stops: generally, 7 a.m. to 9 a.m. and/or 11 a.m. to 1 p.m. (day); and 5 p.m. to 9 p.m. (night).

If the drivers asked questions regarding the questionnaire, the survey team would answer their question and offer a questionnaire information sheet (Appendix D), which provides information on the survey and contact information.

APU Survey Data

A total of 112 survey responses were recorded during the field survey activities. Out of the 112 survey responses, three respondents were local drivers, resulting in a total of 109 long-haul truck drivers completing the APU survey. Table 17 summarizes the number of completed surveys.

Table 17. Number of Completed APU Surveys by Location.

Truck Stop ID	Facility Name	Total Number of Surveys
T195	Hillsboro Loves Travel Stop, Hillsboro, TX	4
T197	Hillsboro TA Travel Center, Hillsboro, TX	78
T240	Italy Loves Travel Stop, Italy, TX	9
T26	Baytown Flying J Travel Plaza, Baytown, TX	20
T98	Dallas Eliza USA (Flying J) Travel Plaza, Dallas, TX	1

Based on the APU survey, approximately 64% of the respondents were operating as part of a fleet[3] as Figure 28 illustrates.

Figure 28. Fleet Truck Percentage.

Approximately 52.3% of the trucks surveyed did not report having an idle reduction technology (IRT) installed. Approximately 36.7% of the trucks operate with either a diesel-powered APU (30.3%) or a battery powered APU (6.4%), as Figure 29 shows. Two of the respondents indicated that their APU system operated on both diesel and batteries. Figure 29 shows the percentage of each of the categories.

3 Trucks operated by individual owners are not considered as part of a fleet.

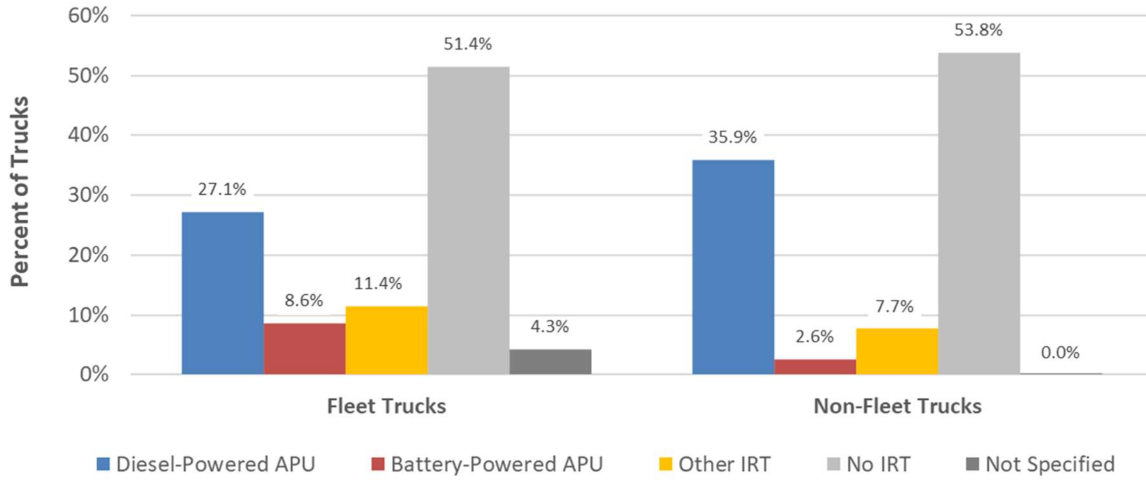


Figure 29. APU Power Source for Fleet and Non-Fleet Trucks.

Figure 30 shows the APU survey responses sorted by truck age. The age groups are based on the EPA' age group source bin used in MOVES. The base year used in determining the age of a truck was 2018. A total of 43% of the respondents operated trucks that were less than three years old. The newer trucks, less than five years old, additionally showed the larger percentages of APU and IRTs than the trucks six years old or older.

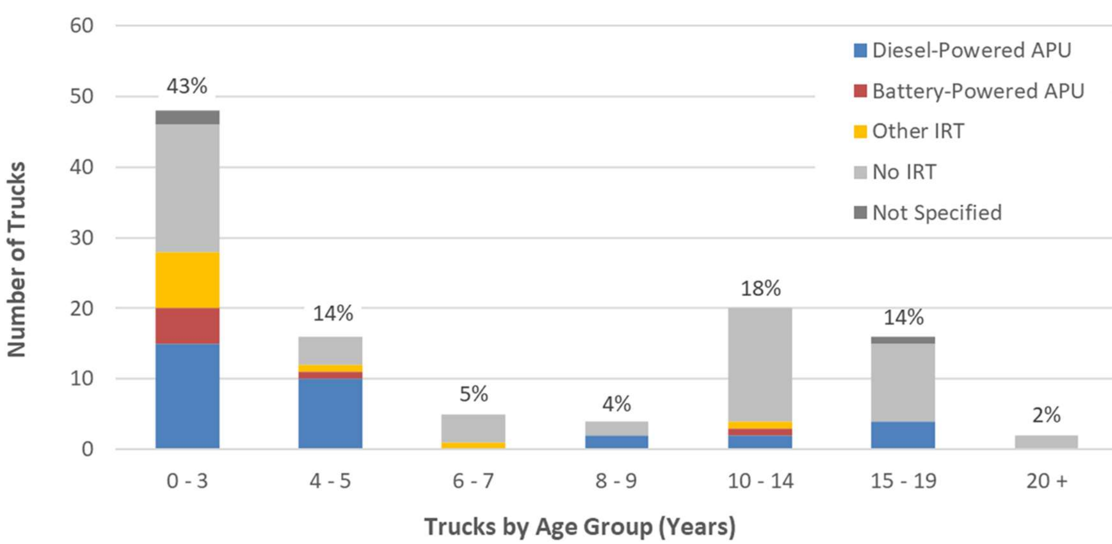


Figure 30. APU Power Source by Truck Age Group.

Data Analysis and Idling Estimation

The truck idling data collection described in the previous chapter yielded an extensive array of truck idling observations. The raw data were assembled in a spreadsheet table format and organized according to facility and hour of the observation. Idling activity parameters were calculated for each hourly observation. The research team performed a series of statistical tests and analyses to identify the independent variables and the structure of the idling estimation model. Findings from the ATRI data analysis were used to verify the assumptions of the hourly distribution of the idling activity and to check for potential seasonal variations. TTI developed an analytical idling estimation model based on the findings of the previous step. This model was implemented as a Microsoft® Excel spreadsheet tool and facility- and county-specific estimates of daily hours of idling were generated.

Data Exploration

The field observations of the trucks stops were organized by facility and hour of the observations. Each observation point represents a snapshot of the number of trucks parked and number of trucks idling. The following parameters were calculated for each observation points:

- Occupancy Rate: defined as the percentage of available truck parking spaces (i.e., facility capacity) where a truck was present; and
- Idling Rate: defined as the percentage of available parking spaces where a truck was idling. Idling rate is mathematically equivalent to the average hours of idling expected to occur on a truck parking space during an hour.

The following observations were made thought an initial examination of the data.

- As Figure 31 shows, rest areas/travel centers’ occupancy and idling trends are prominently different from trucks stops/fueling stations’ trends. On average, rest areas/travel centers have notably higher occupancy and idling rates compared to truck stops. Based on this observation, the data was divided into two subsets based on the facility type and all the subsequent analyses and modeling were conducted separately.

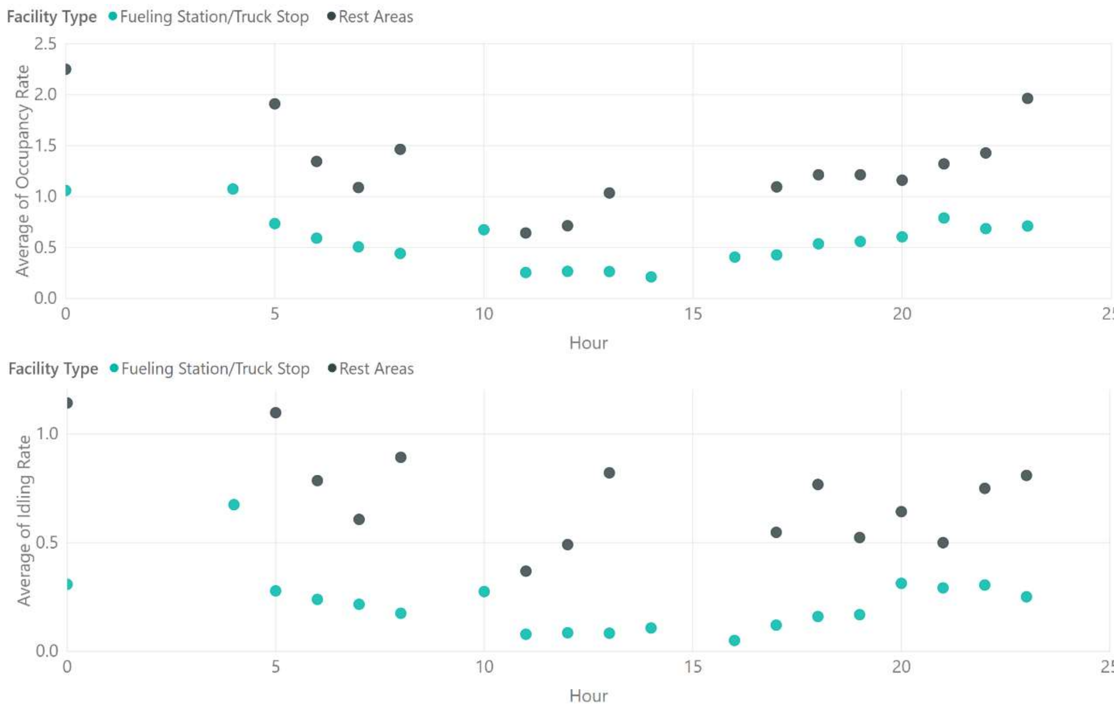


Figure 31. Average Hourly Occupancy and Idling Rate by Facility Type.

- Hourly occupancy rates appear to follow a convex cyclical distribution with the facility utilization (i.e. occupancy rate) peak period occurring between 10 p.m. and 5 a.m. and minimum lot utilization occurring between 11 a.m. and 2 p.m.
- Parking facilities can have an occupancy rate more than 1, which corresponds to the observation of more trucks attempting to park at the facility than the facility's capacity. This usually occurs when trucks park on the side of the roads and side streets adjacent to the facility, or on on/off ramps connecting the facilities to the frontage roads. The field data showed that this behavior was especially prevalent for rest areas/travel centers along the Interstate freeways.
- TTI team examined the hourly distribution of the average idling rate for each of the data collection corridors as Figure 32 shows. Figure 32 shows a relatively consistent idling behavior especially in terms of the shape of the profile.

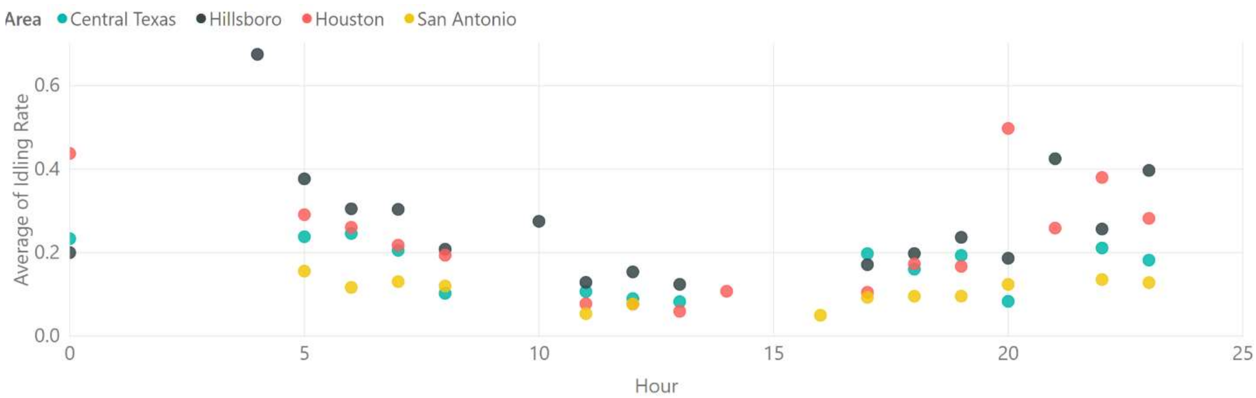


Figure 32. Distribution of Average Idling Rates by Data Collection Corridor.

Statistical Analysis

TTI researchers examined the hourly idling rate distributions for each individual facility. This further investigation revealed a large variability of hourly idling rates as Figure 33 shows. The TTI team examined potential ways to estimate the amount of idling based on a facilities' characteristics. An examination of dependencies between the variables indicated a relationship between the hourly idling rates and occupancy rates. A linear regression analysis confirmed this assumption with a $R^2 = 0.65$ for which both intercept and coefficient are significant at the 95% confidence level. Figure 34 shows the observations and the fitted line.

Figure 33. Hourly Idling Rate by Hour for All Observed Truck Stops.

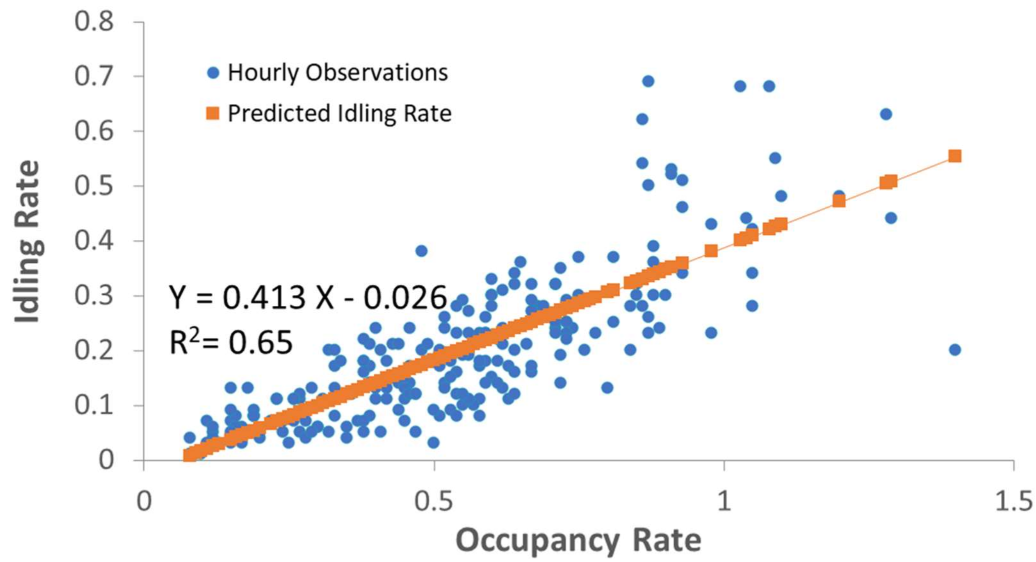
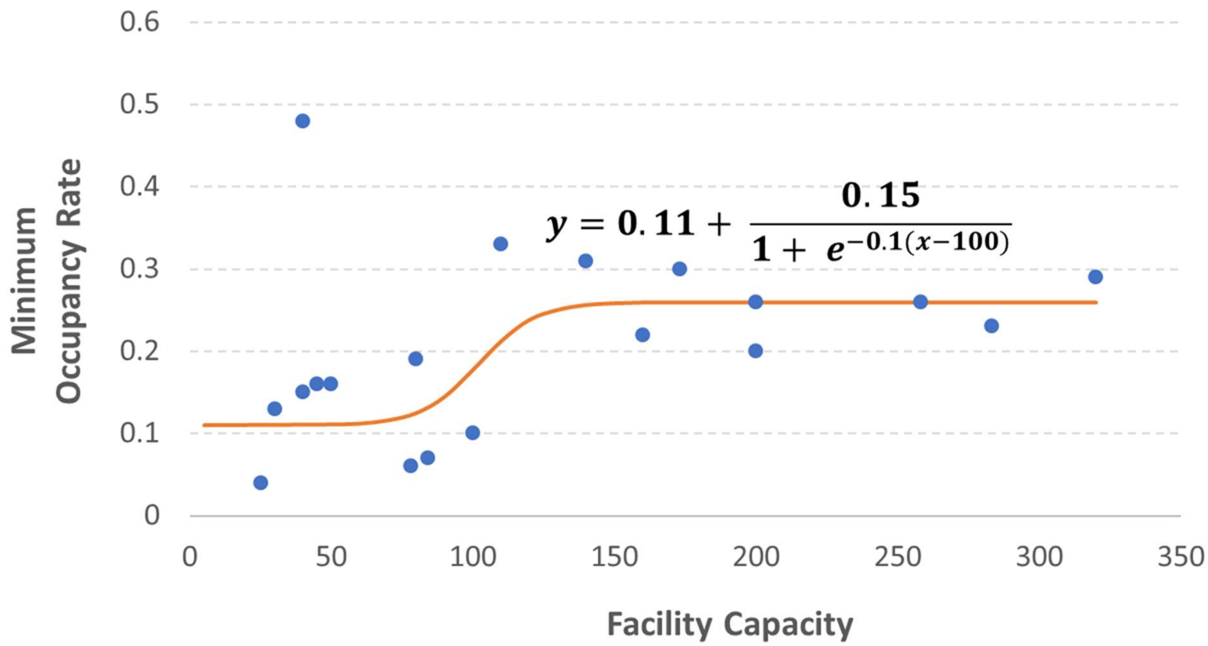


Figure 34. Relationship between Occupancy Rate and Idling Rate for Trucks Stops.

As stated previously, hourly occupancy rates appear to follow a convex cyclical distribution. TTI extracted the average hourly distribution of observed stopped trucks from the ATRI dataset. Figure 34 shows the results from the ATRI dataset. Although this distribution is not equivalent to the occupancy rate, it represents the same phenomenon (i.e., parked trucks) from a different perspective; i.e., actual distribution over two days versus average sample distribution over multiple days. Therefore, the shape of the distribution of stopped trucks from the ATRI dataset would be generally the same as the shape of the occupancy rate distribution.

Because ATRI dataset has a larger sample (i.e., more days and more facilities) than the field observations, the resultant shape of the relationship is considered a strong representation of the *average* occupancy rate distribution. Results from Figure 34 confirm the assumption of a convex cyclical distribution of the occupancy rate distribution over a 24-hour period. This distribution may be approximated by a sinusoid function whose parameters can be calculated from the maximum and minimum occupancy rate.

TTI extracted minimum and maximum occupancy rates from the field observations for each facility. The researchers examined whether the facility-specific minimum and maximum occupancy can be estimated based on the available facility characteristics. Through visual examination of scatter plots, the facility capacity was found to have a potential relationship with the minimum and maximum occupancy rate. A series of linear and non-linear relationships were examined between the minimum and maximum occupancy and facility capacity. A sigmoid curve was found to describe this relationship for the truck stop facilities better than the other examined functional forms. Figure 35 shows the relationship between the minimum occupancy rate and facility capacity. The parameters of the sigmoid function were obtained using a non-linear optimization minimizing the mean squared error. Both charts in Figure 35 reflect typical parking minimum and maximum occupancy and their respective relationships to capacity.



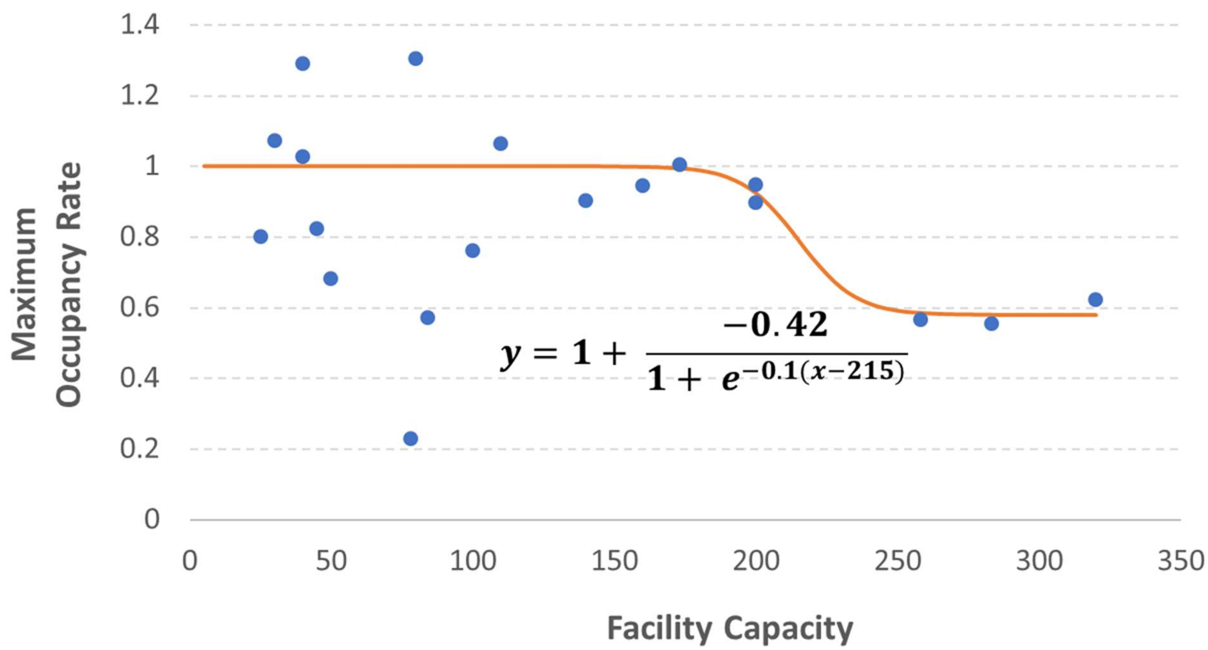


Figure 35. Relationship between Minimum and Maximum Occupancy Rate and Truck Stop Capacity.

The top chart in Figure 35 shows the relationship between capacity and occupancy rate at the minimum demand period (11:00 a.m.). This is consistent with a low demand situation where the smaller facilities are more lightly utilized, possibly a matter of driver choice since these facilities may be less conveniently located and may have fewer amenities (such as food, person rest areas, etc.).

The bottom chart in Figure 35 shows the relationship between capacity and occupancy at the maximum demand period. The chart shows that the facility capacity is a constraint that defines occupancy for all but the largest facilities. This is consistent with facility design, planning and business strategy. Larger facilities are typically located in the highest volume corridors and typically maximize the site (build the maximum number of spaces, extensive amenities, etc.). Consequently, the largest facilities do not reach capacity even at peak demand.

These two parameters, occupancy rate at minimum and maximum demand, are both a function of facility size and are based on empirical field data. The TTI team used these two parameters to establish the relative bounds of occupancy for individual facilities by facility size (i.e., capacity). The resulting range is then used to calibrate a sinusoidal curve representing the hourly distribution of occupancy for each facility, which is in turn used to calculate the facility-specific idling hours.

A constant value of 0.55 is suggested for the minimum occupancy rate of rest areas and travel centers, which corresponds to the 5th percentile of the field observation values for these facility types. Similarly, using the 95th percentile of the filed observation values a value of 2.2 is suggested for the maximum occupancy rate of the rest areas and travel centers.

Extended Idle Estimation Spreadsheet Tool

Relationships shown in Figure 34 and Figure 35 provide a means of estimating hourly idling hours for individual trucks stops. By combining these relationships, TTI developed a facility-specific extended idle estimation method, which follows the following steps.

Step 1. Determine the capacity and type of the facility (truck stop, rest area or travel center, picnic area, Walmart store near a freeway)

Step 2. If a picnic area or Walmart, skip to *Step 7*. Determine the expected facility-specific minimum occupancy rate value using the following guidance:

- Truck stops $Occupancy_{min} = 0.11 + \frac{0.15}{1+e^{-0.1(Capacity-10)}}$
- $Occupancy_{max} = 1.0 - \frac{0.42}{1+e^{-0.1(Capacity-215)}}$
- Rest areas and travel centers $Occupancy_{min} = 0.55$
- $Occupancy_{max} = 2.2$

Step 3. Calculate the following parameters:

- Amplitude $a = {(Occupancy_{max} - Occupancy_{min})}/{2}$
- Vertical Shift $d = {(Occupancy_{max} + Occupancy_{min})}/{2}$
- Phase Shift $c = 6$

Step 4. Calculate hourly occupancy rates using the following equation:

- $Occupancy\ Rate_{hour\ i=0\ to\ 23} = d + a\sin({2\pi}/{24} \times (i-c))$

Step 5. Calculate hourly idling rates using the following equations:

- Truck stops
- $Idling\ Rate_{hour\ i=0\ to\ 23} = 0.38\ Occupancy\ Rate_{hour\ i}$
- Rest areas and travel centers
- $Idling\ Rate_{hour\ i=0\ to\ 23} = 0.064 + 0.49\ Occupancy\ Rate_{hour\ i}$

Step 6. Calculate hourly hours of extended/Hotelling idling using the following equation:

$Hours\ of\ Hoteling\ Idling_{\ hour\ i=0\ to\ 23} = Facility\ Capacity \times Idling\ Rate_{hour\ i}$

Step 7. Calculate daily hours of extended/Hotelling idling using the following equations:

- Truck stops, rest areas, and travel centers
- $Daily\ Hours\ of\ Hoteling\ Idling = \sum_0^{23} Hours\ of\ Hoteling\ Idling_{\ hou\ \ i}$
- Picnic areas $Daily\ Hours\ of\ Hoteling\ Idling = 11.2$
- Walmart stores $Daily\ Hours\ of\ Hoteling\ Idling = 16.8$

Picnic areas and Walmart stores near a freeway usually experience a few trucks stopping overnight. To include them in the county level Hotelling idling calculations, average capacity values of 4 and 6 were assumed for picnic areas and Walmart stores, respectively. The average capacity for a Walmart store is based on the 2013 CAPCOG study, which considered the maximum number of trucks observed during the data collection as the de facto capacity. An average idling rate of 0.28 was applied to these capacities to derive a rough estimate for the expected daily average hours of Hotelling idling for these types of facilities. The previous method was implemented in a spreadsheet tool. The tool is populated by the identified facilities as part of this study, i.e., Fall 2017 facility inventory database.

The equation used for truck stops in Step 7 is slightly different from what was originally obtained from the linear regression in Figure 34. The intercept value from Figure 34 is a negative value that is very close to zero. Because a negative idling rate is unrealistic, researchers made this slight change by setting the intercept to zero and repeat the regression. This change resulted in a marginal increase in the prediction error.

Results

The TTI team used the spreadsheet tool to estimate the total daily hours of idling for a representative weekday. All the results are submitted in a spreadsheet format along with this technical memorandum. Figure 36 shows the aggregated results for the 20 counties with the highest estimated daily hours of idling. The figure also shows the average.

As Figure 36 shows, the estimated hours of Hotelling idling closely follows the same trend as the number of available truck parking spaces in each county. Counties with higher average idling rate, such as El Paso and Hill counties, behave slightly different. For example, although Bexar County has slightly more truck parking spaces than El Paso County, El Paso County has higher estimated idling hours.

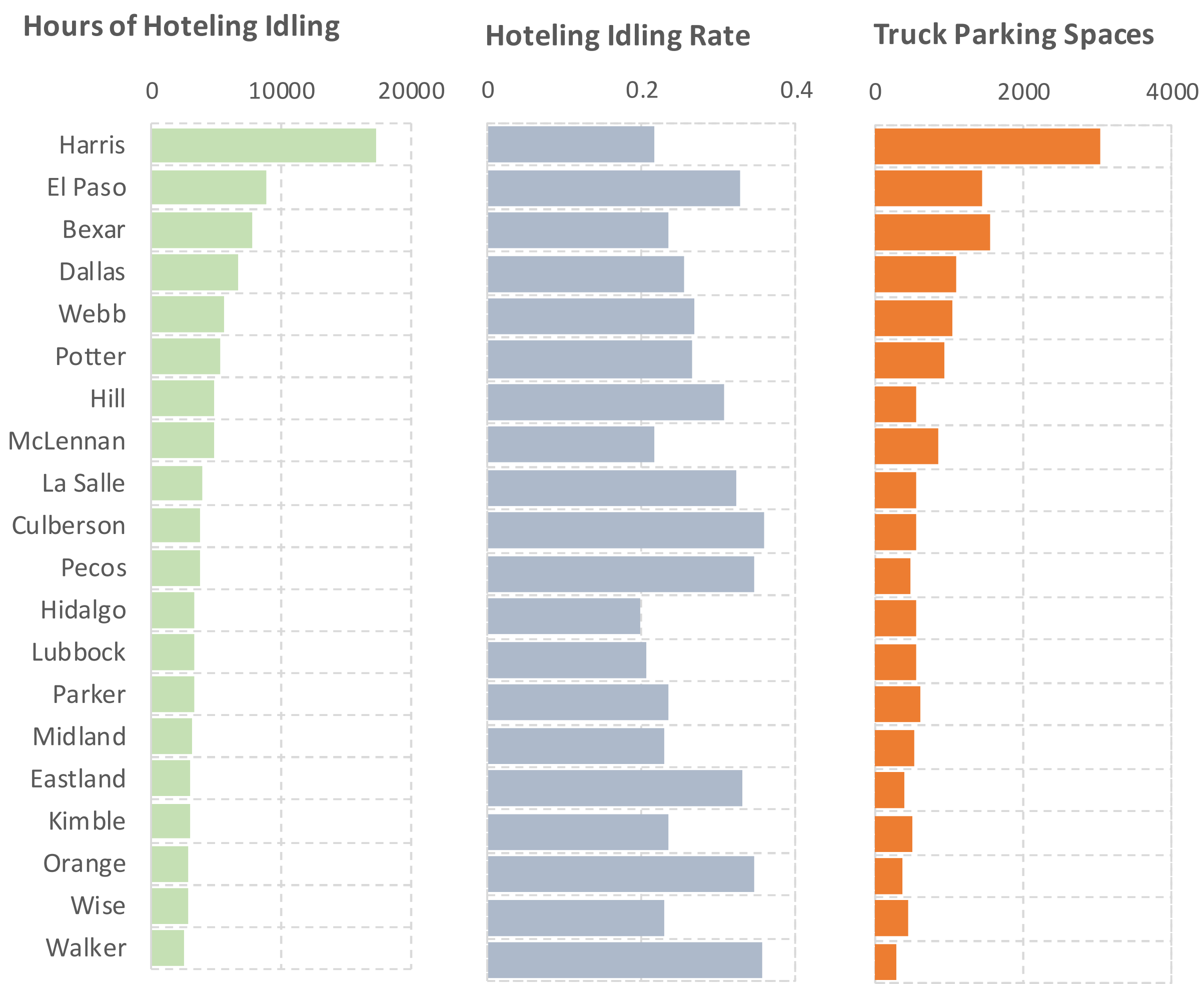


Figure 36. Aggregated Results for the Top 20 Counties.

CHAPTER 4 – DATA ANALYSIS AND LONG-TERM IDLE DATABASE

TASK 4 SUMMARY

Under Task 4, TTI analyzed the data gathered in Task 3 to produce updated long-term idle activity estimates and processed the results into a file formatted for use with MOVES. Activities under Task 4 included:

- analyzing the activity data; and
- processing results of the data analyses and developing MOVES compatible inputs for all Texas counties for all MOVES analysis years: 1990 and 1999 to 2050.

TTI developed and provided the MOVES-compatible long term idle and APU Input database for 254 Texas counties, for all MOVES analysis years. TTI provided the MOVES inputs database (about 25 GB) in "tceq_hotelling_data.zip" (about 6.5 GB) needed for inputting the 1990 and 1999 to 2050 county-specific long term idle and APU information into MOVES county databases.

DATA DESCRIPTION

TTI provided MOVES hotellinghours and hotellingactivitydistribution database tables for use in estimating hotelling activity and emissions with MOVES for all 254 Texas counties and all (53) analysis years, months, and day-types in MOVES.

Hotellinghours input – this MOVES database table has eight columns: six ID columns, one hotelling hours values column, and the last column identifying the data as user input. The fields (with number of unique IDs in parenthesis) are:

- sourceTypeID (1), hourDayID (48), monthID (12), yearID (53), ageID (31), zoneID (254), hotellingHours, isUserInput

The hourDayID values are a combination of hourID (1 through 24) and dayID (2 for weekend, 5 for weekday), e.g., 12, 22, 32… 242 are hourdayIDs for weekends, and 15, 25, 35… 245 are hourdayIDs for weekdays. AgeIDs are 0 through 30, and yearIDs are 1990 and 1999 through 2050. The zoneID values are county FIPS codes concatenated with a zero on the right. The hotellingHours values represent "portion of week" activity, i.e., the sum of hotelling hours for weekend hours for a particular monthID/yearID represents roughly two days of hotelling activity, and similarly for weekday hours represents roughly five days of hotelling activity. This fully populated table for Texas contains 4,535,424 records per yearID, with 240,377,472 total rows.

Hotellingactivitydistribution input– this MOVES database table has four columns of data specifying the fraction of hotelling activity that occurs for four hotelling operating modes. The fields are:

- beginModelYearID, endModelYearID, opModeID, opModeFraction

The four opModeIDs are 200 - Extended Idling of Main Engine, 201 - Hotelling Diesel Auxiliary Power Unit (APU), 203 - Hotelling Battery or AC (plug in), 204 – Hotelling All Engines and Accessories Off. TTI considered using information from responses in the Task 3 trucker's surveys but decided to use this new hotelling activity distribution provided by EPA. EPA based this hotelling activity distribution on their assessment of expected technology use by tractor manufacturers for compliance with Heavy-Duty Greenhouse Gas standards. Note that TTI previously used the MOVES default -- 100% extended idling for 2009 and earlier model years, and for 2010 and later model years, 70% extended idling and 30% diesel APU. This robust, new draft default is more realistic than the current default in that it reflects activity in all four operating modes, which TTI also observed in the Task 3 trucker's survey. These hotellinghours and hotellingactivitydistribution data are appropriate input for both MOVES inventory mode and emission rates mode analyses.

Table 18. MOVES Hotelling Activity Distribution

Begin Model Year	End Model Year	Operating Mode ID			
		200	201	203	204
		Ext Idle	APU	Electric	Off
1960	2009	0.80	0	0	0.20
2010	2020	0.73	0.07	0	0.20
2021	2023	0.48	0.24	0.08	0.20
2024	2026	0.40	0.32	0.08	0.20
2027	2050	0.36	0.32	0.12	0.20

Source: Population and Activity of On-road Vehicles in MOVES201X (EPA draft, August 2017).

OVERVIEW OF METHODOLOGY

TTI used several of its inventory development process utilities to produce the Task 4 hotellinghours deliverable (complete hotellinghours input data set for all Texas counties and analysis years in MOVES as described above), consistent with the statewide, HPMS-based virtual link methodology.

The main hotelling estimation steps involved using TTI's OffNetActCalc utility to produce summer weekday county level hotelling activity estimates for all years, and TTI's MOVESHotellingHrsAnnBuild utility to post-process the OffNetActCalc hourly hotelling activity output to produce the complete MOVES hotellinghours compatible inputs dataset for Texas. The summer weekday hotelling hours output from OffNetActCalc is input to MOVESHotellingHrsAnnBuild along with monthly travel factors and weekend/weekday travel proportions-by-month factors to produce hotelling hours inputs to MOVES, in a tab-delimited textfile format. This procedure expands the summer weekday estimates to annual estimates, allocates these year estimates to the weekday and weekend portions in each month, and finally converts each month's hotelling hours to a one week total (i.e., sum of weekend and weekday hotelling hours by month is the equivalent of one week of hotelling hours). (This is the algorithm TTI used to produce the MOVES annual hotellinghours table for Texas counties for the 2014 AERR inventories for TCEQ.)

TTI wrote and executed MySQL scripts to produce and populate the complete hotellinghours database table for use with MySQL. TTI used latest available data in the analysis and appropriate, available historical data for historical analysis years, along with the new, Texas statewide, 2017 winter weekday, baseline, county-level hotelling activity estimates from Task 3.

The OffNetActCalc utility requires the baseline 24-hour hotelling hours input data, associated baseline link VMT and speeds, base time-of-day VMT mixes, and base vehicle population estimates. The OffNetActCalc utility uses the base input data along with the corresponding analysis scenario input datasets to produce and apply CLHT VMT scaling factors to the base 24-hour hotelling hours; calculates and applies hourly hotelling distributions (i.e., inverse of hourly CLHT VHT); calculates and applies extended idling and diesel APU splits to produce the analysis scenario hourly hotelling hours, extended idle hours and diesel APU hours estimates. The VirtualLinkVMT and VehPopulationBuild utilities were run for all counties and analysis years in order to produce needed inputs to OffNetActCalc utility.

Estimation of SHI and APU Hours

The remaining activity measures needed to estimate the off-network emissions using the mass per activity emissions rates are the hourly, county-level heavy-duty diesel truck (SUT 62, fuel type 2 [CLhT_Diesel]) emissions-producing hotelling activities (i.e., truck main engine idling and diesel APU use). During hotelling, the truck's main engine is assumed to be in extended idle mode or its diesel auxiliary power unit is in use, or it is using electric power or no power. Hotelling hours were first estimated followed by estimation of the SHI and diesel APU hours components of hotelling hours. The following discussion of SHI and APU hours estimation procedures applies only to CLhT_Diesel vehicles.

The hotelling activity estimates were based on information from a TCEQ extended idling study which produced 2017 winter weekday extended idling estimates for each Texas county. Hotelling scaling factors for the analysis year scenario (2017 summer weekday) were applied to the base 2017 winter weekday hotelling values from the study to estimate the 24-hour hotelling. Hotelling hourly factors were then applied to allocate the 24-hour hotelling to each hour of the day. To ensure valid hourly hotelling values were used in the emissions estimation, the hourly hotelling hours were compared to the hourly SHP (i.e., hourly hotelling values cannot exceed the hourly SHP values). SHI and APU hours factors were then applied to the hotelling hours to produce the hourly SHI and APU hours activity.

Hotelling Scaling Factors

To estimate the county-level 24-hour hotelling, county-level hotelling scaling factors were developed for the 2017 summer weekday. These scaling factors were produced using county-level link VMT and speeds and VMT mixes for the hotelling base scenario (2017 winter weekday) and for the 2017 summer weekday analysis scenario. The 2017 winter weekday link-level VMT and speeds were developed similarly to the 2017 summer weekday link-level VMT and speed data except using 2017 winter weekday county VMT control totals. The vehicle type VMT mixes were the same VMT mixes used to estimate emissions in the emissions estimation process.

For each link in the 2017 winter weekday link-level VMT and speeds, the link VMT was allocated to CLhT_Diesel using the base weekday vehicle type VMT mix. This VMT allocation was performed for each link and hour in the base, 2017 winter weekday link VMT and speeds dataset, with the individual link VMT aggregated by hour to produce the hourly and 24-hour 2017 winter weekday VMT applicable to CLhT_Diesel. Using a similar allocation process, the 2017 summer weekday CLhT_Diesel hourly and 24-hour VMT were calculated using the 2017 summer weekday link-level VMT and speeds and the inventory vehicle type VMT mix. The county-level 24-hour hotelling scaling factors were calculated by dividing the CLhT_Diesel 24-hour VMT estimates for the analysis scenario by the estimates for the base scenario.

Hotelling Hourly Factors

Hotelling hourly factors were used to allocate county-level, 24-hour, hotelling hours to each hour of the day. These hotelling hourly factors were calculated as the inverse of the summer weekday hourly VHT fractions. The hourly VHT fractions were first calculated using the hourly VHT from the SHP estimation process (VHT = SHO). The inverses of these hourly VHT fractions were calculated and then normalized across all hours to produce the county-level, hotelling hours hourly distribution for the summer weekday.

Hotelling by Hour Estimation

The initial 2017 summer weekday hotelling by hour was calculated by multiplying the 24-hour 2017 winter weekday hotelling hours by the 2017 summer weekday hotelling scaling (or adjustment) factor and by the summer weekday hotelling hourly factors. A comparison was then made between hourly hotelling and hourly SHP estimates. For each hour where the initial hotelling hours were greater than the SHP, the final hotelling hours estimate was set equal to the SHP, otherwise the initial hotelling hours estimate was set as the final value. All calculations (scaling factors, hotelling hourly factors, and hotelling by hour calculations) were performed by county.

SHI and APU Hours Estimation

The hourly, county-level, hotelling estimates were factored to produce the SHI and APU hours activity components using aggregate extended idle mode and aggregate APU mode fractions. The hotelling hours estimate for each hour was multiplied by the SHI fraction to calculate the hourly SHI, and by the APU fraction to calculate the APU hours.

The aggregate SHI and the APU fractions were estimated using model year travel fractions (based on source type age distribution and relative mileage accumulation rates used in the MOVES runs) and the updated MOVES hotelling distributions shown in Table 19.[4] The associated travel fractions were applied to the appropriate extended idle and APU operating mode fractions (of the hotelling operating mode distribution) by model year and summed within each mode to estimate the aggregate (across model years) individual SHI and APU fractions. (The sum of the resulting SHI and APU fractions, when subtracted from 1.0, leaves the portion of hotelling hours in which trucks were using electric power or using no power.)

[4] Population and Activity of On-road Vehicles in MOVES201X (page 87 of unpublished report), https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=328870.

Table 19. Hotelling Activity Distributions by Model Year

First Model Year	Last Model Year	Operating Mode Fraction by ID and Name			
		200	201	203	204
		ExtendIdling	Diesel Aux	Battery AC	APU Off
1960	2009	0.80	0	0	0.20
2010	2020	0.73	0.07	0	0.20
2021	2023	0.48	0.24	0.08	0.20
2024	2026	0.40	0.32	0.08	0.20
2027	2050	0.36	0.32	0.12	0.20

Annual Factors

To estimate the annual emissions and build the annual MOVES inventory mode databases in a consistent manner (i.e., so that annualized summer weekday activity will be closely replicated by a MOVES inventory mode run), the summer weekday activity was converted to annual activity based on the MOVES calculation procedures to a format suitable for use with the MOVES inventory mode. This annual activity was then used to construct the activity annualization factors that were applied during the annual emissions estimation process. Activity annualization procedures follow for VMT, hotelling hours, starts, and SHP.

Annual VMT and Annualization Factors

The MOVES calculation procedure for VMT allocates annual VMT by the MOVES defined HPMS vehicle types to summer weekday VMT by HPMS vehicle type using month VMT fractions, day VMT fractions, number of days in the month, and the number of days in the period for the day VMT fraction. The formula for the MOVES VMT allocation procedure is:

$$SWkdVMT_{HPMSVtype} = AVMT_{HPMSVtype} * monthFract_{Month} * dayFract_{Month,DayType} / (noOfDays/7) / noOfRealDays$$

Where:

$SWkdVMT_{HPMSVtype}$ = summer weekday VMT by HPMS vehicle type;

$AVMT_{HPMSVtype}$ = annual VMT by HPMS vehicle type;

$monthFract_{Month}$ = month VMT fraction for the desired month;

$dayFract_{Month,DayType}$ = day VMT fraction for the desired day type (weekday or weekend day by month);

noOfDays	=	number of days in the desired month; and
noOfRealDays	=	number of days in the desired day type (5 for weekday, 2 for weekend day).

Since the objective is to estimate annual VMT from the summer weekday VMT, the formula from the MOVES VMT allocation procedure can be transformed to calculate the annual VMT from the summer weekday VMT by reversing the calculations. The formula for calculating the annual VMT by HPMS vehicle type from the summer weekday VMT is:

$$AVMT_{HPMSVtype} = SWkdVMT_{HPMSVtype} * noOfRealDays *(noOfDays/7)/ dayFract_{Month,DayType} / monthFract_{Month}$$

The number of days in the day type (noOfRealDays) and number of days in the month (noOfDays) were determined by the emissions inventory being annualized. Since the inventories were for summer (July) weekday, the number of days in the day type was set to 5 and the number of days in the month was set to 31. Day VMT fractions and month VMT fractions were developed by TxDOT district using aggregated ATR data (years 2007 - 2016). For each county, this calculation procedure was applied to the summer weekday VMT for each HPMS vehicle type (output from the MOVESactivityInputBuild utility) and saved for use in building the annual MOVES inventory mode databases. The county-level VMT annualization factor was then calculated by dividing the county total annual VMT by the county total summer weekday VMT.

Annual Hotelling Hours and Annualization Factors

The annual hotelling hours were calculated using similar logic and input parameters as the VMT annualization procedure. Since the hotelling hours input to MOVES is required by age, the hourly summer weekday hotelling hours (from the emissions inventory development process) was distributed to each age category using travel fractions. The hourly summer weekday hotelling hours by age was then converted to hourly annual hotelling hours by age. The hourly annual hotelling hours by age was then converted to the proper format for use with the MOVES inventory mode databases (hotelling hours by month, day type, hour, and age). The county total annual hotelling hours were then used to calculate the hotelling annualization factor, which was used during the emissions annualization process to annualize the SHI and APU hours activity.

Travel fractions were used to distribute the hourly summer weekday hotelling hours to each of the MOVES age categories. These travel fractions were calculated using the county-specific age distribution for SUT 62 (also used in the MOVES emissions rate runs) and the county-specific relative mileage accumulation rates (adjusted to reflect the VMT mix in the summer weekday emissions inventory) for SUT 62. The travel fractions by age were calculated by multiplying the age distribution by the relative mileage accumulation rates for each age and dividing by the sum of the product for all the age categories. The travel fractions were calculated using the following formula:

$$TF_{Age} = (STAD_{Age} * RelMAR_{Age}) / \sum(STAD_{Age} * RelMAR_{Age})$$

Where:

TF_{Age}	=	the travel fractions by age category;
$STAD_{Age}$	=	source type age distribution for SUT 62 by age;
$RelMAR_{Age}$	=	relative mileage accumulation rates by age (adjusted to reflect the VMT mix in the summer weekday emissions inventory) for SUT 62 by age; and
$\sum(\,)$	=	sum of ($STAD_{Age}$ * $RelMAR_{Age}$) across all age categories.

The travel fractions were then used to calculate the hourly summer weekday hotelling hours by age from the hourly summer weekday hotelling hours used in the emissions inventory development process. The hourly summer weekday hotelling hours by age were calculated using the following formula:

$$SWkdHH_{Hour,Age} = SWkdHH_{Hour} * TF_{Age}$$

Where:

$SWkdHH_{Hour,Age}$	=	hourly summer weekday hotelling hours by age;
$SWkdHH_{Hour}$	=	hourly summer weekday hotelling hours from the emissions inventory development process; and
TF_{Age}	=	the travel fractions by age category.

The hourly annual hotelling hours by age were then calculated using a similar procedure to the annual VMT using the day and month fractions:

$$AHH_{Hour,Age} = SWkdHH_{Hour,Age} * noOfRealDays *(noOfDays/7)/ dayFract_{Month,DayType} / monthFract_{Month}$$

Where:

$AHH_{Hour,Age}$	=	hourly annual hotelling hours by age;
$SWkdHH_{Hour,Age}$	=	hourly summer weekday hotelling hours by age;
noOfRealDays	=	number of days in the desired day type – 5 for summer weekday;
noOfDays	=	number of days in the desired month – 31 for summer (July) weekday;
$dayFract_{Month,DayType}$	=	day VMT fraction for summer (July) weekday; and
$monthFract_{Month}$	=	month VMT fraction for summer (July).

Since the annual MOVES inventory mode databases also require the hotelling hours input for each month and day type (weekday and weekend day) portions of the week, the annual hotelling hours by age were calculated for each month and day type period (total of 24 sets of hotelling hours) using the following formula:

$$HH_{Month,DayPeriod,Hour,Age} = AHH_{Hour,Age} * monthFract_{Month} * dayFract_{Month,DayType} / (noOfDays/7)$$

Where:

$HH_{Month,DayPeriod,Hour,Age}$	=	hotelling hours by month, day type period, hour, and age;
$AHH_{Hour,Age}$	=	hourly annual hotelling hours by age;
$monthFract_{Month}$	=	month VMT fraction;
$dayFract_{Month,DayType}$	=	day VMT fraction; and
$noOfDays$	=	number of days in the month.

The hotelling annualization factor was then calculated by dividing the county total hotelling hours by the county total summer weekday hotelling hours. This hotelling annualization factor was used for annualizing the SHI and APU hours activity in the emissions annualization process.

CHAPTER 5 – EMISSIONS INVENTORY DEVELOPMENT

INTRODUCTION

Chapter 5 documents the development of emissions inventories using the data and associated revised procedures developed in Tasks 2 through 4. Under Task 5, TTI has produced statewide 2017 combination long-haul truck emissions inventories using the winter 2017 long term idle and APU data. The new data were processed and loaded into MOVES2014a county databases for development of the 2017 AERR EIs. The CDBs were used to develop emissions inventories that include criteria air pollutants (CAP) and CAP precursors, as well as the hazardous air pollutants (HAP). Since the Task 5 inventory year was changed from 2014 to 2017, there are no existing EIs developed for the same year using the previous 2004 truck idling data. To provide the assessment of the amount of change in the EIs between using the 2017 winter data and the 2014 data TTI has produced 2017 combination long-haul truck idling emissions inventories using the previous (2004) truck idling data that include criteria air pollutants (CAP) and CAP precursors, as well as the hazardous air pollutants (HAP). TTI loaded modified long-term idle activity results reflecting the earlier (2004) truck idling data, into existing MOVES2014a county database files (CDBs) and other emissions inventory (EI) development files for analysis year 2017, and developed modified statewide 2017 emissions inventories for selected urban areas using the modified CDBs and inventory utility files. The Task 5 results includes: the statewide long term idle EI using the winter 2017 data (a subset of the 2017 AERR); and, for selected areas a comparison of the EI results using the 2004 idle data and the winter 2017 data.

A pre-analysis plan was prepared and approved by the TCEQ Project Manager documenting the MOVES modeling approach, inventory inputs, and inventory development procedures.

EMISSIONS INVENTORY DEVELOPMENT

Activities completed under this task included:

- Prepare the winter 2017 long term idle inputs that were processed into MOVES county databases and other inventory development utility files used to support development of the on-road 2017 Air Emissions Reporting Requirements (AERR) emissions inventories into inputs for a statewide 2017 combination long haul truck EI;

- For analysis year 2017, incorporate the previous 2014 long term idle inputs into existing MOVES county databases and other inventory development utility files that were previously created to support development of the on-road 2017 Air Emissions Reporting Requirements (AERR) emissions inventories;
- Use the 2017 AERR MOVES CDBs based upon the winter-2017 data to develop emissions estimates for combination long-haul truck long-term idling and APU use, for all Texas counties for analysis year 2017 (subset of the 2017 AERR);
- Use the modified MOVES CDBs to develop emissions estimates for combination long-haul truck long-term idling and APU use, for selected Texas counties for analysis year 2017 based on the earlier (2004) for comparison with the 2017 results;
- Process the results into standard on-road EI formats for Texas, and;
- Document the results and the comparison of results in the Project Report.

Overview of Methodology

Heavy-Duty Vehicle Idle Activity Study – Task 5: Emissions Inventory Development

The Texas A&M Transportation Institute (TTI) developed a detailed pre-analysis plan for estimating 2017 analysis year combination long-haul truck hotelling operating mode emissions with MOVES2014a, using the new, Texas, statewide, county-level local hotelling activity estimates (produced in Task 4 of this Grant Activities Description (GAD)). This plan, required under Task 5, documents the MOVES modeling approach, inventory inputs, and inventory development procedures, and was provided to the Texas Commission on Environmental Quality (TCEQ) project manager for concurrence.

GAD Update Note – The methodology used includes minor, non-material changes to requirements in the Proposal for Grant Activities (PGA) Task 5 approach. The main difference is the general method of inventory development. MOVES inventory mode was used; whereas the earlier PGA method indicated the use of MOVES rates mode in combination with the TTI inventory development utilities. By using the MOVES inventory mode, this approach refines the GAD Task 5 requirements as follows:

- Replaces the use of TTI's detailed link-based inventory development utilities (which require MOVES "rates mode" county input databases [CDBs] in MOVES rates mode runs), as used in the 2017 AERR inventories development;

- Replaces the use of MOVES rates mode in developing the inventories; and
- Eliminates the requirement for two sets of CDBs (a rates mode set and an inventory mode set) – only the inventory mode CDBs used to develop the inventories were provided.

Following this section, the methodology overview is organized as follows: main steps in the process, itemized description detailing the inventories, additional MOVES inputs detail (Addendum 1), and quality assurance guide to be used by TTI during the inventory development process (Addendum 2).

Due to schedule changes and revised priorities during the course of this study, inventory data from the recently completed project 2017 AERR which used the data provided under Task 4 was available, thus satisfying the original requirement of this task to provide inventories using the new data for all 254 counties. For the second requirement of this task (the impact of the new data compared to the earlier data), selected counties from the 254 2017 AERR inventories were modified using the earlier (2004) data, to produce the hotelling emissions inventories using the MOVES inventory mode. Annual and summer weekday estimates were produced for selected Texas counties (of pollutants as listed by inventory period in Table 2 and Table 3). A comparison of hotelling mode activity and emissions estimates between the 2017 AERR study and the modified AERR 2017 project is included. (The modified AERR 2017 project represents the AERR 2017 results using the pre-truck idling study method and data.)

In inventory mode, MOVES produces inventory output (activity and emissions per hour, day, year, etc.). In rates mode, MOVES produces tables of emissions rates from which emissions factors are selected for multiplying by associated activity estimates in external emissions calculations. MOVES inventory mode was selected as optimal over rates mode for producing the single vehicle category inventories. (Rates mode is typically used for a complete fleet mix of gasoline and diesel vehicle types and the full gamut of roadway-based and off-network-based emissions processes, for use in the external, link-based emissions calculations for up to thousands of travel model network links.)

For each county inventory of the 2017 AERR project, a pair of MOVES county-scale inventory mode CDBs were produced – a summer weekday inventory mode CDB and an annual inventory mode CDB. TCEQ provided TTI with the annual MOVES inventory mode CDBs for the selected Texas counties from the 2017 AERR analysis.[1] TTI modified these CDBs with previous (pre-truck idling activity study) hotelling data and produced county-level 2017 summer weekday and county-level 2017 annual emissions inventories for selected counties for combination long-haul diesel truck hotelling activities.

The general emissions inventory development process employed is as follows:

A. **Assemble Data** – TTI used the following data:
    1. Annual inventory mode CDBs for both 2017 summer weekday and annual MOVES inventory mode runs from the TCEQ's 2017 AERR inventories project (provided by TCEQ).
    2. MOVES hotellinghours table input data and hotellingactivitydistribution table input data for 2017 for each county (new estimates product of Task 4).
    3. Texas Low-Emission Diesel (TxLED) oxides of nitrogen (NO_x) adjustment factors from the 2017 AERR inventories project.

B. **Update CDBs** – TTI modified selected CDBs from the 2017 AERR for use in the MOVES inventory mode runs by replacing existing hotellingactivitydistribution and hotellinghours table data for each county with the input data from the previous hotelling method / approach.

C. **MOVES Inventory Mode Runs** – TTI created MOVES run specifications set up with the modified CDBs, and executed the runs to produce the initial summer weekday and annual county level inventories for selected counties. Results for the MOVES county-scale inventory runs were output in a single MOVES output database for each inventory period. MOVES output aggregation levels is hourly and year totals for summer weekday and annual periods, respectively.

D. **TxLED Adjustments** – TTI adjusted the NO_x emissions results for counties in the TxLED program using the TxLED factors from the 2017 AERR inventories project.

E. **Output Formats** – In addition to the MOVES output and post-processed (TxLED-adjusted) output in MySQL databases, TTI exported the final results in tab-delimited text files, for ease of use in spreadsheets. Tab-files for summer weekday include

[1] As noted above, TTI was responsible for all 254 Texas counties of the 2017 AERR inventories analysis. Details on the production of the MOVES annual inventory mode CDBs (the AERR 2017 inventory data to be used in this analysis) may be found in *2017 On-Road Mobile Source Annual, Summer Weekday and Winter Weekday Emissions Inventories: 214 Counties* (and also in the seven companion documents – one for each of seven Texas urban areas) TTI, August 2019.

hourly output, and for annual emissions include year totals. (See Item 6, for pollutants included.)

F. **Provide Inventory Data** –
   1. *Electronic data submittal document* – listing of all files submitted, with descriptions and naming conventions.
   2. *MOVES input data* – 2017 MOVES CDBs, MOVES county-scale inventory mode run specifications, MySQL scripts used to process input data for the MOVES runs (e.g., to produce updated CDBs), TxLED factors used, MySQL scripts used to process MOVES input data.
   3. *Inventory results* – standard set of inventory summary files – tab-delimited text file with hourly and 24-hour activity and emissions summaries by county for summer weekday period, and tab-delimited text file with year total activity and emissions summaries by county for annual period.
   4. *All other relevant data relating to Task 5* – including MOVES output databases, post-processing scripts, TxLED adjustment factor, and spreadsheet summaries (e.g., hotelling inventory comparison of 2017 AERR results and Task 5 results).

G. **Not Provided** – Task 5 of the original GAD specifies that an "additional set of 2017 MOVES inventory-mode CDBs…." will be provided. However, as described in B and C above, MOVES inventory mode CDBs were used in MOVES county-scale inventory mode runs to produce the inventories. Thus, an extra set of inventory mode CDBs was not needed (and would have been identical to those used in the MOVES runs).

Additional itemized details follow.

EMISSIONS INVENTORY DESCRIPTION

1. **Methodology:** MOVES county-scale inventory mode with local hotelling hours and local hotelling activity distribution (extended idling and auxiliary power unit (APU) usage proportions) inputs, with post-processing of MOVES inventory output to incorporate TxLED effects on NO_x emissions.
2. **Geography:** Selected Texas counties.
3. **Analysis Years:** 2017.
4. **Seasonal Periods:** Average Summer Weekday (average Monday through Friday for the June through August period); Annual (January 1 through December 31 period).
5. **Sources:** Combination long-haul diesel truck only.

6. **Pollutants:** There are 54 MOVES2014a pollutants specified for development in the inventory estimates, including eight criteria air pollutants (CAPs) and CAP precursors (Table 2), and 46 hazardous air pollutants (HAPs) (Table 3). (MOVES excludes dioxins and furans and particular metals emissions rates for all processes except exhaust running, thus fewer HAPs are included than in the original 2017 AERR project.)
7. **Emissions Processes**: Extended Idle Exhaust, Crankcase Extended Idle Exhaust, Auxiliary Power Exhaust.
8. **Inventory Electronic Data:** The following inventory data were developed and are provided.

- Standard tab-delimited 2017 summer weekday inventory data file of hourly and 24-hour activity and emissions (pounds/day) summaries for off-network hotelling processes by diesel combination long-haul trucks – source hours idling (SHI), APU hours, and pollutant/process emissions totals for all selected Texas counties.
- Standard tab-delimited 2017 annual inventory data file of year total activity and emissions (pounds/year) summaries for off-network hotelling processes by diesel combination long-haul trucks – SHI, APU hours, and pollutant/process emissions totals.
- Spreadsheet summaries of the inventory results with comparison to 2017 AERR hotelling emissions inventory data.
- MOVES runspec input files, CDBs, and MySQL files (scripts) used to process the inventory mode CDBs used to develop the inventories as well as all MOVES input and output and any data files and scripts used to post-process the MOVES output to the final adjusted (e.g., for TxLED effects) results.
- NOTE: Not provided – MOVES "rates" mode runs were not performed in producing the inventories (MOVES inventory mode was used), thus no MOVES rates mode files were provided.

9. **Inventory Process:** The following describes the overall process. MySQL scripts were written and used to update the existing annual CDBs with the hotelling input data previously used. MOVES runspecs were developed by county and temporal scenario (summer weekday and year). MOVES runs were executed to produce one MOVES inventory output database each for summer weekday and annual. Results were post-processed to incorporate TxLED effects, where needed. Summaries were exported to tab-delimited text files and summarized in spreadsheets. Addendum 1 provides more detail on MOVES inputs. Note that, even though this is not a formal full inventory,

appropraite quality assurance checks were performed throughout the process. The QA guide is included as Addendum 2.

- Assembled databases and data files:
  - Copied selected annual MOVES CDBs to the MySQL data folder;
  - Copied previous Texas hotelling activity database to MySQL data folder;
  - Copied TxLED factor to an appropriate location; and
  - Made filenames for new CDBs, MOVES run specification (MRS) files, MOVES output databases, post-processed output databases, post-processed output data files (the output databases and summary files contain the data for the selected counties for each analysis [summer weekday, annual]).
- Prepared CDBs for MOVES inventory runs by updating CDB hotelling data:
  - Wrote and executed MySQL script for annual CDBs that:
    - Copied and renamed each annual CDB;
    - Deleted all data from the hotellinghours and hotellingactivitydistribution tables in each annual CDB copy; and
    - Populated the hotellinghours and hotellingactivitydistribution tables with the appropriate, previous, Texas 2017 annual hotellinghours data (i.e., 17,856 rows – by 31 ages, 24 hours of a weekday, 24 hours of a weekend day, and by 12 months of the year).
- Created MRS files:
  - For summer weekday created an MRS file for each county that specifies:
    - County scale inventory mode;
    - July, 2017, weekday, all 24 hours;
    - State and county name, annual CDB;
    - Diesel combination long-haul truck, off-network road type;
    - CAPs, CAP precursors, and greenhouse gases (GHG) (listed in Table 2);
    - Extended idle, crankcase extended idle, and APU exhaust;
    - Output into one Texas summer weekday database for all selected counties with units of pounds, kilojoules, and miles, and save all activity output; and
    - Detail level - county, hour, road type, source type, fuel type, and emissions process.
  - For annual inventories, created an MRS file for each county that specifies:
    - County scale inventory mode;
    - All months, 2017, both weekday and weekend day, all 24 hours;
    - State and county name, annual CDB;

- ♣ Diesel combination long-haul truck, off-network road type;
- ♣ CAPs, CAP precursors, GHGs, and HAPs listed in Table 2 and Table 3;
- ♣ Extended idle, crankcase extended idle, and APU exhaust;
- ♣ Output into one Texas annual database for all counties with units of pounds, kilojoules, and miles, and save all activity output; and
- ♣ Detail level - county, year, road type, source type, fuel type, and emissions process.

- Executed MOVES runs (both sets – one with the new and one with the previous hotelling activity input data).
- Filtered results and applied TxLED adjustment to NO_x emissions:
  - o Filtered out pollutants not required (see Table 2 and Table 3); and
  - o Applied Table 1 factor to NO_x emissions for the 110 Texas counties in the TxLED program.

Table 20. 2017 TxLED Reduction Factors.

Diesel Fuel Source Use Type	Reduction	Adjustment[1] Factor
Combination Long-Haul Truck	5.46%	0.9454

1 Source: 2017 AERR inventories project (TTI August 2019).

- Exported data, format as appropriate:
  - o Wrote and executed scripts to export inventory summaries to tab-delimited text files; and
  - o Produced spreadsheet summaries and made the comparisons.

Table 21. CAPs and CAP Precursors in Daily and Annual Inventories.

MOVES Pollutant ID	Pollutant Name	NEI Pollutant Code
2	Carbon Monoxide (CO)	CO
3	Oxides of Nitrogen (NO_x)	NOX
30	Ammonia (NH_3)	NH3
31	Sulfur Dioxide (SO_2)	SO2
87	Volatile Organic Compounds (VOC)	VOC
90	Atmospheric CO_2	CO2
100	Primary Exhaust Particulate Matter (PM_{10}) - Total	PM10-PRI
110	Primary Exhaust $PM_{2.5}$ - Total	PM25-PRI

Table 22. HAPs to be Included in Annual Inventories.

Category	MOVES ID		Pollutant Name	NEI Code
Gaseous HC	20		Benzene	71432
	21		Ethanol	64175
	22		MTBE	1634044
	24		1,3-Butadiene	106990
	25		Formaldehyde	50000
	26		Acetaldehyde	75070
	27		Acrolein	107028
	40		2,2,4-Trimethylpentane	540841
	41		Ethyl Benzene	100414
	42		Hexane	110543
	43		Propionaldehyde	123386
	44		Styrene	100425
	45		Toluene	108883
	46		Xylene	1330207
Polycyclic Aromatic Hydrocarbons (PAH)	**Gas**	**PM**		
	170	70	Acenaphthene	83329
	171	71	Acenaphthylene	208968
	172	72	Anthracene	120127
	173	73	Benz(a)anthracene	56553
	174	74	Benzo(a)pyrene	50328
	175	75	Benzo(b)fluoranthene	205992
	176	76	Benzo(g,h,i)perylene	191242
	177	77	Benzo(k)fluoranthene	207089
	178	78	Chrysene	218019
	168	68	Dibenzo(a,h)anthracene	53703
	169	69	Fluoranthene	206440
	181	81	Fluorene	86737
	182	82	Indeno(1,2,3,c,d)pyrene	193395
	185	23	Naphthalene	91203
	183	83	Phenanthrene	85018
	184	84	Pyrene	129000

Addendum 1

Summer Weekday and Annual MOVES Inventory Inputs
MOVES RunSpecs (MRS), County Databases (CDB), Outputs, and Post-Processing

Note that the following described input, output and post-processing was applied twice – once with the new hotelling activity inputs, and once with the previous hotelling activity input data.

MOVES Inputs and Output:

- MRS input files: 508 - one per county for summer weekday and for annual.
- CDB inputs: 254 - one per county.
- The MOVES default input database (MOVESDB20161117).
- MOVES output databases: 2 – one for summer weekday and one for annual.
- MOVES run log output text files: 2 per county – one for summer weekday and one for annual.

Post-Processing MOVES Output:

- Emissions were filtered and copied to a separate database table (named differently, e.g., emissions_tti) - filtered to exclude extra pollutants not requested in the task but which were required in the computation of required pollutants.
- TxLED factor was applied to all NO_x emissions for the counties in the TxLED program.
- The filtered and adjusted results were identifiable (e.g., in file name) as final, TxLED adjusted, results.

MRS and CDB Descriptions:

Table 23 and Table 24 describe the MOVES summer and annual Runspec selections. Table 25 lists the CDB tables and data sources.

Table 23. Summer Weekday MOVES RunSpec Selections by GUI Panel.

Navigation Panel	Detail Panel	Selection
Scale	Model; Domain/Scale; Calculation Type	Onroad; County; Inventory
Time Spans	Time Aggregation Level; Years – Months – Days – Hours	Hour; 2017 – 7 – Weekday – All
Geographic Bounds[1]	Region; Selections; Domain Input Database	County; <*COUNTYNAME*>[1]; <*mvs14a_2017ann_COUNTYFIPS_extidle_ei_cdb_in*>[1]
On-Road Vehicle Equipment	Source Use Type (SUT)/Fuel Combinations	Combination Long-Haul Truck/Diesel
Road Type	Selected Road Types	Off-Network
Pollutants and Processes[2]	VOC; CO; NOx; SO_2; NH_3; Atmospheric CO_2; $PM_{2.5}$ and PM_{10} Total Exhaust	Extended Idle Exhaust, Crankcase Extended Idle Exhaust, Auxiliary Power Exhaust
Manage Input Data Sets	Additional Input Database Selections	None
Strategies	Rate Of Progress	Not Applicable
General Output	Output Database; Units; Activity	< *mvs14a_2017swkd_texas_extidle_ei_out* >; Pounds, KiloJoules, Miles; Select all activity types
Output Emissions Detail	Always; For All Vehicles/Equipment; On Road	Time: Hour – Location: County – Pollutant; Fuel Type, Emissions Process; Road Type, Source Use Type
Advanced Performance Measures	Aggregation and Data Handling	All check boxes are to be "un-checked"

[1] County name for county of run is selected, CDB name (includes county FIPS code), and output database includes "Texas" in name since it will contain results for selected Texas counties.

[2] "Chained" pollutants require other pollutants (not listed in the table) to be selected. Pollutants required for chaining, but not required in the inventories will be removed from rate tables before the emissions calculations. These pollutants include: total gaseous hydrocarbons, non-methane hydrocarbons, total energy consumption, organic carbon, elemental carbon, sulfate (SO_4), composite non-elemental carbon PM, and H_2O (aerosol).

Table 24. Annual MOVES RunSpec Selections by GUI Panel.

Navigation Panel	Detail Panel	Selection
Scale	Model; Domain/Scale; Calculation Type	Onroad; County; Inventory
Time Spans	Time Aggregation Level; Years – Months – Days – Hours	Hour; 2017 – All 12 – Weekday and Weekend day – All 24
Geographic Bounds[1]	Region; Selections; Domain Input Database	County; <*COUNTYNAME*>[1]; <*mvs14a_2017ann_COUNTYFIPS_extidle_ei_cdb_in*>[1]
On-Road Vehicle Equipment	SUT/Fuel Combinations	Combination Long-Haul Truck/ Diesel
Road Type	Selected Road Types	Off-Network
Pollutants and Processes[2,3]	VOC; CO; NOx; SO_2; NH_3; Atmospheric CO_2; $PM_{2.5}$ and PM_{10} Total Exhaust; and the applicable MOVES HAPs	Extended Idle Exhaust, Crankcase Extended Idle Exhaust, Auxiliary Power Exhaust
Manage Input Data Sets	Additional Input Database Selections	None
Strategies	Rate Of Progress	Not Applicable
General Output	Output Database; Units; Activity	< *mvs14a_2017ann_texas_extidle_ei_out* >; Pounds, KiloJoules, Miles; Select all activity types
Output Emissions Detail	Always; For All Vehicles/Equipment; On Road	Time: Year – Location: County – Pollutant; Fuel Type, Emissions Process; Road Type, Source Use Type
Advanced Performance Measures	Aggregation and Data Handling	All check boxes are to be "un-checked"

[1] County name for county of run is selected, CDB name (includes county FIPS code) output database includes "texas" in name since it will contain results for selected Texas counties.

[2] The HAPs in MOVES, as listed in Tables 1 and 2 of *Air Toxic Emissions from On-road Vehicles in MOVES2014*, EPA, November 2015, will be included (i.e., those with individual pollutantids, consisting of 14 hydrocarbons and volatile organic compounds (VOCs) and 32 PAHs), but the 17 dioxins and furans and 7 metals listed in Tables 3 and 4, which are not included for the MOVES diesel hotelling mode process emission rates, will not be included.

[3] "Chained" pollutants require other pollutants (not listed in the table) to be selected. Pollutants required for chaining, but not required in the inventories will be removed from rate tables before the emissions calculations. These pollutants include: total gaseous hydrocarbons, non-methane hydrocarbons, total energy consumption, organic carbon, elemental carbon, sulfate (SO_4), composite non-elemental carbon particulate matter (PM), and H_2O (aerosol).

Table 25. Annual MOVES Inventory Mode CDB Data Sources.

Table	Data Source[1]
avft	A
avgspeeddistribution	A
county	A
countyyear	A
dayvmtfraction	A
fuelsupply	A
fuelformulation	A
hotellingactivitydistribution	A (B)
hotellinghours	A (B)
hourvmtfraction	A
hpmsvtypeyear	A
imcoverage	A
monthvmtfraction	A
roadtype	A
roadtypedistribution	A
sourcetypeage	A
sourcetypeagedistribution	A
sourcetypeyear	A
starts	A
state	A
year	A
zone	A
zonemonthhour	A
zoneroadtype	A

[1] Data source "A" is the corresponding 2017 AERR annual inventory mode CDB which includes the corresponding county seasonal and annual new data from Task 4 of this study. Data source "B" is the corresponding county seasonal and annual previous data prior to this study. .

Addendum 2

Quality Assurance Checks

The criteria for passing quality checks and the checks typically performed on each major inventory input component (e.g., estimates of source activity, activity distributions, emissions factors) as well as on the resulting emissions estimates, are summarized in the following. These QA guidelines were used to ensure that the development of emissions inventory estimates are as accurate as possible and meet the requirements of TCEQ's intended use.

Specifically, TTI verified that the overall scope of the emissions analysis is met as prescribed in the pre-analysis plan, to include:

- Purpose of the emissions analysis (i.e., initial application of new Texas hotelling activity data sets in MOVES emissions modeling);
- Extent of the modeling domain (e.g., analysis years, geographic coverage, seasonal periods, days, sources, pollutants, processes);
- Methods, models, and data used (e.g., default versus local input data sources); and
- Procedures and tools used and all required emissions output data sets are produced.

TTI performed checks on input data preparation, model or utility execution instructions (e.g., run specifications, scripts, job control files [JCFs], command files), and output, as appropriate to the component:

Input data preparation checks:

- Verify the basis of input data sets against the pre-analysis plan: Actual historical or latest available data, validated model, expected values or regulated limits, regulatory program design, model defaults, surrogates, data from prior analyses, professional judgment; check aggregation levels;
- Data development: Depending on the procedure and input dataset, calculations may be verified (e.g., re-calculated independently and compared with originally prepared values – if spot-checking a series of results, include extremes and intermediate values);
- Completeness: Verify that input datasets are within the required dimensions, and all required fields are populated and properly coded or labeled;
- Format: Verify that formats are within required specifications (e.g., field positions, data types and formats, and file formats), if any;
- Reasonability checks: (discussed later); and
- Ensure that any inputs provided from external sources are quality assured, as listed previously.

Checks on model or utility execution instructions:

- Verify that the correct number of utility or model run specifications are prepared for each application (e.g., by year, county, season, day type); and
- Verify that each utility or model run script includes the correct modeling specifications (e.g., commands, input values, input and output file paths, output options [e.g., units, temporal aggregation level]) for the application per applicable guide.

Check for the successful completion of model and utility executions:

- Verify that the correct number of each type of output file was produced by the model or utility;
- Check for any unusual output file sizes;
- Search output (e.g., utility listing files or model execution logs that contain error and warning records) for warnings/errors; and
- Check the summary information provided in the output listing files for any unusual results.

Finally, TTI performed further checks for consistency, completeness, and reasonability of data output from model or utility applications:

- Verify that the data distributions and allocation factors produced or used sum to 1.0, as appropriate (e.g., hourly activity factors within a time period, proportion of travel by vehicle categories on a given roadway category);
- Verify that the required data fields are present, populated, and properly coded or labeled; verify that data and file formats are within specifications;   Verify that any activity, emissions rate, or emissions adjustments were performed as intended (e.g., seasonal activity factor, emissions control program adjustment);
- For datasets prepared with temporal or geographic variation (e.g., activity distributions between weekends/weekdays, vehicle mix, or average speeds between road types or time periods), compare and note whether directional differences are as expected;
- Check for consistency between datasets (e.g., input activity versus output activity, disaggregate data versus data summaries);
- Calculate county, 24-hour, aggregate emissions rates (from aggregate activity by type and associated emissions output) and compare the rates between counties examining the results for outliers while assessing the reasonability of any relative and directional differences (e.g., qualify based on activity distributions by road type and speed, mix of vehicles by road type, meteorological variation, control program coverage). Compare the results to results from previous emissions analyses if available.

Summary of Findings

This section summarizes the differences associated with the two truck idling sources (2017 winter and 2004 summer truck idling data) for selected urban areas. Recall from the previous chapter that inventories have been produced for all 254 counties using the data collected for this study. The emissions from the 254 county inventories using the data from this study are documented fully in the 2017 AERR reports and summarized in a separate electronic appendix to this report (thus fulfilling the comprehensive inventory with new idling data requirement of Task 5). This section "backs out" the new data and replaces it with the earlier data (from 2004) for four areas to demonstrate the impact of the new data on emissions. Dallas-Fort Worth, El Paso, Houston-Galveston-Brazoria, and San Antonio Hotelling, Extended Idling, and APU hours, and emission estimates summary are provided in sixteen separate tables (one set of four for each selected urban area, labeled Tables 1a – 4d). All are 2017 AERR estimates of hoteling, extended idling and APU hours activity using 2017 and 2004 winter and summer data, respectively (one table for each area), followed by the associated emissions (three tables of emissions for each area).

Table 1a. Dallas Fort Worth Hotelling, Extended Idling & APU Hours

FIPS	COUNTY	2017AERR Projected using 2017 Winter Data			2017AERR Projected Using 2004 Summer Data		
		Hotelling (hrs)	Extended Idling (hrs)	APU (hrs)	Hotelling (hrs)	Extended Idling (hrs)	APU (hrs)
48085	Collin	2,970.72	2,267.64	108.93	4,409.18	3,365.66	161.68
48113	Dallas	16,769.24	12,800.48	614.91	9,844.95	7,514.96	361.00
48121	Denton	4,875.33	3,721.49	178.77	3,784.69	2,888.97	138.78
48139	Ellis	4,850.14	3,702.26	177.85	3,640.38	2,778.82	133.49
48221	Hood	113.21	86.42	4.15	0.00	0.00	0.00
48231	Hunt	3,318.41	2,533.04	121.68	1,138.74	869.24	41.76
48251	Johnson	762.38	581.95	27.96	240.23	183.38	8.81
48257	Kaufman	4,742.39	3,620.02	173.90	5,744.47	4,384.93	210.64
48367	Parker	7,376.57	5,630.76	270.49	5,991.12	4,573.20	219.69
48397	Rockwall	3,018.57	2,304.17	110.69	2,981.81	2,276.11	109.34
48439	Tarrant	6,128.33	4,677.95	224.72	4,264.44	3,255.18	156.37
48497	Wise	6,081.65	4,642.31	223.01	2,501.61	1,909.55	91.73
Total		61,006.96	46,568.51	2,237.06	44,541.62	34,000.00	1,633.29

Table 1b. Dallas Fort Worth Carbon Monoxide Emissions (pounds)

FIPS	COUNTY	2017AERR Projected using 2017 Winter Data		2017AERR Projected Using 2004 Summer Data	
		Extended Idling	APU	Extended Idling	APU
48085	Collin	447.36	8.65	663.98	12.83
48113	Dallas	2,525.30	48.80	1,482.56	28.65
48121	Denton	734.18	14.19	569.94	11.01
48139	Ellis	730.39	14.12	548.21	10.59
48221	Hood	17.05	0.33	0.00	0.00
48231	Hunt	499.72	9.66	171.48	3.31
48251	Johnson	114.81	2.22	36.18	0.70
48257	Kaufman	714.16	13.80	865.07	16.72
48367	Parker	1,110.85	21.47	902.21	17.44
48397	Rockwall	454.57	8.78	449.04	8.68
48439	Tarrant	922.87	17.84	642.19	12.41
48497	Wise	915.84	17.70	376.72	7.28
Total		9,187.12	177.55	6,707.58	129.63

Table 1c. Dallas Fort Worth Nitrogen Oxides Emissions (pounds)

FIPS	COUNTY	2017AERR Projected using 2017 Winter Data		2017AERR Projected Using 2004 Summer Data	
		Extended Idling	APU	Extended Idling	APU
48085	Collin	842.85	5.34	1,250.97	7.92
48113	Dallas	4,890.89	30.97	2,871.36	18.18
48121	Denton	1,424.24	9.02	1,105.63	7.00
48139	Ellis	1,419.88	8.99	1,065.72	6.75
48221	Hood	33.58	0.21	0.00	0.00
48231	Hunt	965.60	6.11	331.36	2.10
48251	Johnson	218.64	1.38	68.89	0.44
48257	Kaufman	1,385.33	8.77	1,678.05	10.63
48367	Parker	2,189.53	13.86	1,778.30	11.26
48397	Rockwall	864.51	5.47	853.98	5.41
48439	Tarrant	1,801.40	11.41	1,253.52	7.94
48497	Wise	1,790.64	11.34	736.55	4.66
Total		17,827.09	112.88	12,994.34	82.28

Table 1d. Dallas Fort Worth Volatile Organic Compounds Emissions (pounds)

FIPS	COUNTY	2017AERR Projected using 2017 Winter Data		2017AERR Projected Using 2004 Summer Data	
		Extended Idling	APU	Extended Idling	APU
48085	Collin	194.42	1.81	288.56	2.68
48113	Dallas	1,097.47	10.21	644.31	6.00
48121	Denton	319.07	2.97	247.69	2.30
48139	Ellis	317.42	2.95	238.25	2.22
48221	Hood	7.41	0.07	0.00	0.00
48231	Hunt	217.17	2.02	74.53	0.69
48251	Johnson	49.89	0.46	15.72	0.15
48257	Kaufman	310.37	2.89	375.95	3.50
48367	Parker	482.76	4.49	392.09	3.65
48397	Rockwall	197.55	1.84	195.15	1.82
48439	Tarrant	401.07	3.73	279.09	2.60
48497	Wise	398.02	3.70	163.72	1.52
Total		3,992.61	37.15	2,915.04	27.12

Table 2a. Houston-Galveston-Brazoria Hotelling, Extended Idling & APU Hours

FIPS	COUNTY	2017AERR Projected using 2017 Winter Data			2017AERR Projected Using 2004 Summer Data		
		Hotelling (hrs)	Extended Idling (hrs)	APU (hrs)	Hotelling (hrs)	Extended Idling (hrs)	APU (hrs)
48039	Brazoria	1,470.40	1,122.40	53.92	224.04	171.01	8.22
48071	Chambers	4,601.10	3,512.17	168.72	2,447.16	1,867.99	89.73
48157	Fort Bend	4,639.91	3,541.79	170.14	5,105.49	3,897.18	187.21
48167	Galveston	455.55	347.74	16.70	641.90	489.98	23.54
48201	Harris	42,407.16	32,370.71	1,555.03	22,586.65	17,241.09	828.23
48291	Liberty	1,527.84	1,166.25	56.02	473.85	361.70	17.38
48339	Montgomery	6,115.66	4,668.28	224.26	5,944.39	4,537.54	217.97
48473	Waller	3,777.77	2,883.69	138.53	2,818.85	2,151.72	103.36
Total		64,995.41	49,613.01	2,383.31	40,242.33	30,718.22	1,475.64

Table 2b. Houston-Galveston-Brazoria Carbon Monoxide Emissions (pounds)

FIPS	COUNTY	2017AERR Projected using 2017 Winter Data		2017AERR Projected Using 2004 Summer Data	
		Extended Idling	APU	Extended Idling	APU
48039	Brazoria	221.43	4.28	33.74	0.65
48071	Chambers	692.89	13.39	368.52	7.12
48157	Fort Bend	698.73	13.50	768.84	14.86
48167	Galveston	68.60	1.33	96.66	1.87
48201	Harris	6,386.15	123.42	3,401.35	65.73
48291	Liberty	230.08	4.45	71.36	1.38
48339	Montgomery	920.97	17.80	895.17	17.30
48473	Waller	568.90	10.99	424.49	8.20
	Total	9,787.74	189.16	6,060.14	117.12

Table 2c. Houston-Galveston-Brazoria Nitrogen Oxides Emissions (pounds)

FIPS	COUNTY	2017AERR Projected using 2017 Winter Data		2017AERR Projected Using 2004 Summer Data	
		Extended Idling	APU	Extended Idling	APU
48039	Brazoria	417.56	2.64	63.62	0.40
48071	Chambers	1,305.36	8.27	694.27	4.40
48157	Fort Bend	1,316.54	8.34	1,448.65	9.17
48167	Galveston	129.24	0.82	182.11	1.15
48201	Harris	12,070.74	76.43	6,429.05	40.71
48291	Liberty	435.03	2.75	134.92	0.85
48339	Montgomery	1,741.51	11.03	1,692.74	10.72
48473	Waller	1,071.77	6.79	799.72	5.06
	Total	18,487.75	117.07	11,445.08	72.47

Table 2d. Houston-Galveston-Brazoria Volatile Organic Compounds Emissions (pounds)

FIPS	COUNTY	2017AERR Projected using 2017 Winter Data		2017AERR Projected Using 2004 Summer Data	
		Extended Idling	APU	Extended Idling	APU
48039	Brazoria	96.23	0.90	14.66	0.14
48071	Chambers	301.12	2.80	160.16	1.49
48157	Fort Bend	303.66	2.83	334.13	3.11
48167	Galveston	29.81	0.28	42.01	0.39
48201	Harris	2,775.35	25.82	1,478.19	13.75
48291	Liberty	99.99	0.93	31.01	0.29
48339	Montgomery	400.24	3.72	389.03	3.62
48473	Waller	247.24	2.30	184.48	1.72
Total		4,253.64	39.58	2,633.67	24.51

Table 3a. El Paso Hotelling, Extended Idling & APU Hours

FIPS	COUNTY	2017AERR Projected using 2017 Winter Data			2017AERR Projected Using 2004 Summer Data		
		Hotelling (hrs)	Extended Idling (hrs)	APU (hrs)	Hotelling (hrs)	Extended Idling (hrs)	APU (hrs)
48141	El Paso	18,946.76	14,462.65	694.76	11,341.52	8,657.34	415.88
Total		18,946.76	14,462.65	694.76	11,341.52	8,657.34	415.88

Table 3b. El Paso Carbon Monoxide Emissions (pounds)

FIPS	COUNTY	2017AERR Projected using 2017 Winter Data		2017AERR Projected Using 2004 Summer Data	
		Extended Idling	APU	Extended Idling	APU
48141	El Paso	2,853.22	55.14	1,707.93	33.01
Total		2,853.22	55.14	1,707.93	33.01

Table 3c. El Paso Nitrogen Oxides Emissions (pounds)

FIPS	COUNTY	2017AERR Projected using 2017 Winter Data		2017AERR Projected Using 2004 Summer Data	
		Extended Idling	APU	Extended Idling	APU
48141	El Paso	6,523.33	41.31	3,904.87	24.73
Total		6,523.33	41.31	3,904.87	24.73

Table 3d. El Paso Volatile Organic Compounds Emissions (pounds)

FIPS	COUNTY	2017AERR Projected using 2017 Winter Data		2017AERR Projected Using 2004 Summer Data	
		Extended Idling	APU	Extended Idling	APU
48141	El Paso	1,239.98	11.54	742.25	6.91
Total		1,239.98	11.54	742.25	6.91

Table 4a. San Antonio Hotelling, Extended Idling & APU hours

FIPS	COUNTY	2017AERR Projected using 2017 Winter Data			2017AERR Projected Using 2004 Summer Data		
		Hotelling (hrs)	Extended Idling (hrs)	APU (hrs)	Hotelling (hrs)	Extended Idling (hrs)	APU (hrs)
48029	Bexar	19,403.33	14,811.17	711.50	7,097.21	5,417.52	260.25
48091	Comal	5,242.61	4,001.85	192.24	1,350.40	1,030.80	49.52
48187	Guadalupe	5,338.02	4,074.68	195.74	432.71	330.30	15.87
48259	Kendall	1,470.67	1,122.61	53.93	176.82	134.98	6.48
48493	Wilson	0.00	0.00	0.00	27.63	0.00	0.00
Total		31,454.64	24,010.30	1,153.41	9,084.76	6,913.59	332.12

Table 4b. San Antonio Carbon Monoxide Emissions (pounds)

FIPS	COUNTY	2017AERR Projected using 2017 Winter Data		2017AERR Projected Using 2004 Summer Data	
		Extended Idling	APU	Extended Idling	APU
48029	Bexar	2,921.97	56.47	1,068.78	20.65
48091	Comal	789.49	15.26	203.36	3.93
48187	Guadalupe	803.86	15.54	65.16	1.26
48259	Kendall	221.47	4.28	26.63	0.51
48493	Wilson	0.00	0.00	0.00	0.00
Total		4,736.79	91.54	1,363.93	26.36

Table 4c. San Antonio Nitrogen Oxides Emissions (pounds)

FIPS	COUNTY	2017AERR Projected using 2017 Winter Data		2017AERR Projected Using 2004 Summer Data	
		Extended Idling	APU	Extended Idling	APU
48029	Bexar	5,642.64	35.73	2,063.92	13.07
48091	Comal	1,532.65	9.70	394.78	2.50
48187	Guadalupe	1,555.92	9.85	126.12	0.80
48259	Kendall	454.01	2.87	54.59	0.35
48493	Wilson	0.00	0.00	0.00	0.00
Total		9,185.21	58.16	2,639.42	16.71

Table 4d. San Antonio Volatile Organic Compounds Emissions (pounds)

FIPS	COUNTY	2017AERR Projected using 2017 Winter Data		2017AERR Projected Using 2004 Summer Data	
		Extended Idling	APU	Extended Idling	APU
48029	Bexar	1,269.86	11.82	464.48	4.32
48091	Comal	343.10	3.19	88.38	0.82
48187	Guadalupe	349.35	3.25	28.32	0.26
48259	Kendall	96.25	0.90	11.57	0.11
48493	Wilson	0.00	0.00	0.00	0.00
Total		2,058.56	19.15	592.75	5.52

APPENDIX A. MOVES HOTELLING ACTIVITY METHODOLOGY

This appendix provides an overview of how hotelling activity is currently calculated in the MOVES2014a model. This MOVES2014a model methodology is based on using vehicle miles of travel (VMT) and speed on a rural freeway as a surrogate to estimate county-level aggregate data compared to the TTI methodology described in Appendix B.

This chapter focuses on how hotelling activity is developed and applied in county-level emissions estimation. In MOVES2014a, hotelling is defined as a long period of time that drivers spend in their combination heavy-duty trucks during rest hours of long-distance driving. In MOVES2014a, all hotelling processes only apply to long-haul combination trucks (source type 62). All the long-haul combination trucks are using diesel fuel. The MOVES database contains three hotelling related tables: HotelingActivityDistribution, HotelingCalendarYear, and HotelingHours. Hotelling includes activities from Extended Idle, Diesel Auxiliary Power, Battery Power, and Engine-Off operations. Table 26 shows the MOVES operating modes.

Table 26. Hotelling Operating Modes.

opModeID	Operating Mode Name
200	Extended Idling
201	Hotelling Diesel Auxiliary Power Unit (APU)
203	Hotelling Battery or AC (plug in)
204	Hotelling APU Off (engine-off)

A.1 HOTELINGCALENDARYEAR

HotelingCalendarYear is a table where the national average rate of hotelling hours is stored. For MOVES, the total hours of driving are estimated by using the national estimate of total VMT by long-haul combination trucks divided by an estimated average speed. It is assumed that, on average 10 hours were spent driving per long-distance trip, while on average eight-hours of rest time were spent during each trip. The total hours of hoteling are then estimated as total hours of driving divided by average time per driving and multiplied by the average time per hotelling per driving. The national average hotelling rate is calculated by national total hours of hoteling divided by the national estimate of total VMT by long-haul combination trucks on rural restricted access roads. The value calculated for analysis year 2011 is used as the default for all calendar years. The steps of calculation are described in Equation 1 though Equation 4 (*19*).

$$Total\ Hours = \frac{Total\ VMT}{Average\ Speed} \qquad \text{Equation 1}$$

$$Total\ Trips = \frac{Total\ Hours}{10\ hours\ per\ trip} \qquad \text{Equation 2}$$

$$Hotelling\ Hours = Total\ Trips\ \times 8\ hours\ per\ trip \qquad \text{Equation 3}$$

$$Hotelling\ Rate = \frac{Hotelling\ Hours}{Total\ VMT\ on\ Rural\ Restricted\ Access} \qquad \text{Equation 4}$$

Where,

- $Total\ VMT$ = national total miles traveled by long-haul combination trucks on all road types in calendar year 2011;
- $Total\ Hours$ = total time of long-haul combination trucks spend on driving;
- $Average\ Speed$ = estimated average speed for long-haul combination trucks while moving on all road types;
- $Total\ Trips$ = estimated number of long-distance trips by long-haul combination trucks;
- $Hotelling\ Hours$ = total time drivers of long-haul combination trucks spend on resting; and
- $Total\ VMT\ on\ Rural\ Restricted\ Access$ = national total miles traveled by long-haul combination trucks on rural restricted access in calendar year 2011.

A.2 HOTELINGACTIVITYDISTRIBUTION

In most cases, users should rely on the national default hotelling operating mode fractions. However, if users have detailed local hotelling data, the MOVES County Data Manager includes the HotellingActivityDistribution table to be used to input the local estimate of hotelling hours that are in each of the hotelling modes by model year. Table 27 shows the national default HotellingActivityDistribution table in the MOVES database. All the hotelling hours for long-haul trucks of model years before 2010 are assumed to use extended idle to power accessories. Beginning with the 2010 model year, the trucks are assumed to use extended idle 70% of the time and use APUs the remaining 30% of the time.

Table 27. MOVES Default HotellingActivityDistribution Table.

beginModelYearID	endModelYearID	opModeID	opModeFraction
1960	2009	200	1
2010	2050	200	0.7
1960	2009	201	0
2010	2050	201	0.3
1960	2009	203	0
2010	2050	203	0
1960	2009	204	0
2010	2050	204	0

A.3 HotelingHours

In most cases, users should rely on the MOVES generated hotelling hours, which are determined based on the amount of rural restricted access VMT imported. The MOVES County Data Manager feature for inputting local data also includes the HotelingHours table as an optional input for local specific hotelling hours. This input can be used if users have detailed local information on total hotelling hours by hour of day, day type, month, and vehicle model year. Note that a complete table must be provided that includes all combinations of SourcetypeID, MonthID, HourDayID, YearID, AgeID, ZoneID, and hotelingHours selected in the RunSpec.

APPENDIX B. TEXAS' METHODOLOGY FOR ESTIMATING HOTELLING ACTIVITY

The current ("TTI") method for estimating long-haul truck hotelling activity by operating mode developed by TTI is a component of the larger, MOVES-based on-road mobile source fleet-wide county-level emissions inventory process. MOVES emissions rates are combined with on-network and off-network activity estimates to calculate emissions. Roadway-based emissions are calculated for each link in a transportation network (or Highway Performance Monitoring System [HPMS] roadway/area type category), and off-network emissions (e.g., parked vehicle evaporative, start exhaust, hotelling exhaust) are calculated as county-level totals (*20*,*21*).

During hoteling, the truck's main engine is assumed to be in idling mode or its auxiliary power unit is in use. For an emissions inventory scenario, hotelling hours are first estimated then allocated to the source hours extended idling (SHI) and APU hours activity components. The diesel combination long-haul truck SHI and APU hours estimation process main components, for a seasonal day type (e.g., summer weekday), are:

- Base year, 24-hour hotelling hours estimates;
- Scaling factors for adjusting base hotelling to analysis year seasonal day-type scenario;
- Hotelling hourly factors for allocating 24-hour values to hour of day;
- Source hours parked estimates as a limit (validity check) on hotelling hours estimates; and
- SHI and APU hours factors to distribute hourly hotelling by operating mode.

To calculate hotelling emissions hotelling activity by operating mode must be estimated for each county of the study area by hour of day. Since the hotelling operating mode distributions may vary by model year, the operating mode-specific activity estimates are also calculated by the 31 age categories in MOVES. Activity estimates are then aggregated within operating modes for application with MOVES aggregate emissions rates by operating mode.

The current basis of TTI's hotelling activity estimates is a 2004 county-level statewide HDV extended idling activity data set estimated by ERG. Since 2004 is prior to the year when APUs began penetrating the market (distributions in MOVES show APU operating mode fractions are zero until 2010), the ERG 2004 extended idling hour estimates were assumed equal to hotelling hours (i.e., hotelling hours = extended idling hours + APU hours = 100% + 0%). The TTI procedure produces and applies growth factors to forecast as well as to backcast activity estimates to reflect the year and day type of the study. Annual estimates are typically a conversion from seasonal day type.

B.1 Hotelling Hours Scaling Factors

To estimate the county-level 24-hour hotelling hours for the scenario, county-level hotelling hours scaling factors are developed using a diesel combination long-haul truck VMT ratio. This ratio is county, analysis year, seasonal day-type scenario VMT divided by county, base VMT (i.e., 2004 summer weekday), for diesel combination long-haul trucks. The VMT estimates for the analysis scenario are from the on-road inventory process (HPMS-based VMT and speeds, with source type and fuel type VMT mix applied). Activity estimates are similarly made for the base case.

B.2 Hotelling Hourly Factors

To allocate the inventory scenario, county-level, 24-hour hotelling by hour of the day, and county-level hotelling hourly factors for each inventory scenario are used. These hotelling hourly factors are calculated as the inverse of the county-level analysis scenario hourly vehicle hours travelled (VHT) fractions. The county-level hourly VHT fractions are first calculated using the inventory scenario hourly source hours operating (SHO) (i.e., SHO = VHT) from the source hours parked (SHP) estimation process. The inverse of these hourly VHT fractions are then calculated and normalized to produce the county-level, analysis scenario, hotelling hour factors.

B.3 County-Level Hotelling by Hour Estimation

The initial analysis scenario hotelling by hour estimates are calculated by multiplying the 24-hour base hotelling hours by the analysis scenario scaling factor and hotelling hourly factors. A comparison is then made between hourly hotelling and hourly SHP for the scenario. For each hour where the analysis scenario initial hotelling value is greater than the SHP, the final hotelling estimate is set equal to the SHP; otherwise the initial hotelling estimate is set as the final value. All calculations (scaling factors, hotelling hourly factors, and hotelling by hour calculations) are performed by county.

B.4 County-Level SHI and APU Hours Estimation

The hourly hotelling estimates for each county are then allocated to the SHI and APU hours activity components using extended idle mode and APU mode fractions. The aggregate extended idle fractions and the APU fractions are estimated using model year travel fractions (based on local source type age distribution estimates and MOVES default relative mileage accumulation rates) and the MOVES default hotelling activity distribution (i.e., a distribution of 1.0 SHI [and 0.0 APU hours] prior to the 2010 vehicle model year and a 0.7/0.3 SHI/APU activity allocation for 2010 and later model years).

The associated travel fractions are applied to the extended idle and APU operating mode fractions, by model year, and summed within each mode to estimate the aggregate (across model years) individual SHI and APU fractions (which sum to 1.0). For each hour, the analysis scenario hotelling hours are multiplied by the SHI fraction to calculate the analysis scenario hourly SHI activity and by the APU fraction to calculate the analysis scenario hourly APU hours activity.

APPENDIX C. DATA SOURCES

TTI will acquire and process various traditional and emerging high-resolution data sets to complete this study. TTI will link various data sets together into a complete, holistic system model that leverages the value of each independent data set, and that can be used to achieve the study goals with increased detail and accuracy. The following lists the non-exhaustive sources that TTI has access to and can use in this project.

C.1 TxDOT Roadway Inventory Data

Description: TxDOT publishes a series of roadway inventory reports on an annual basis that contain statistics on the use of public roadways in the state. TxDOT submits this data annually to the Federal Highway Administration (FHWA) as part of the HPMS program. Figure 37 shows one of the summaries from this data set.

Link to Overview for this Series of Tables

			Summary of Centerline Miles, Lane Miles, Truck DVMT and Total DVMT; by County; by Year						
			2014				2015		
County Name	TxDOT County Code	TxDOT District Name	Centerline Miles	Lane Miles	Truck DVMT	Total DVMT	Centerline Miles	Lane Miles	Truck DVMT
Anderson	1	Tyler	1,506.010	3,115.861	126,410.120	1,309,320.090	1,506.010	3,115.861	150,780.402
Andrews	2	Odessa	611.293	1,302.425	283,884.134	1,083,483.250	611.293	1,302.425	145,622.905
Angelina	3	Lufkin	1,444.371	3,076.943	356,736.240	2,117,269.140	1,444.371	3,076.943	324,034.106
Aransas	4	Corpus Christi	381.368	803.805	77,890.427	494,547.832	381.368	803.805	54,523.249
Archer	5	Wichita Falls	749.477	1,519.834	78,940.300	387,378.314	749.477	1,519.834	68,958.256
Armstrong	6	Amarillo	599.100	1,269.135	122,972.590	344,014.839	599.100	1,269.135	111,627.990
Atascosa	7	San Antonio	1,290.930	2,743.022	579,695.546	2,405,864.308	1,290.930	2,743.022	458,941.154
Austin	8	Yoakum	1,010.164	2,076.535	339,383.110	1,334,746.750	1,010.164	2,076.535	312,535.478
Bailey	9	Lubbock	1,050.888	2,139.615	43,828.108	249,824.949	1,050.888	2,139.615	36,097.713
Bandera	10	San Antonio	652.807	1,329.809	41,653.968	403,191.295	652.807	1,329.809	48,182.587
Bastrop	11	Austin	1,380.137	2,915.849	243,856.333	2,359,326.992	1,380.137	2,915.849	235,489.114
Baylor	12	Wichita Falls	594.590	1,265.552	57,539.041	207,107.065	594.590	1,265.552	52,128.148
Bee	13	Corpus Christi	823.117	1,736.470	166,350.952	856,316.266	823.117	1,736.470	201,587.450

Figure 37. County-Level Centerline and Lane Miles Summary of TxDOT Roadway Inventory Data.

Source: TxDOT.

Measured Variables: Data includes centerline miles, lane miles, daily VMT, and daily truck VMT.

Temporal Coverage: The data are annual average daily for 2005 to 2015.

Spatial Coverage: Includes all 254 counties in Texas. The reports are summarized at county, district, and state levels and are grouped by highway system, ownership, functional classification, population classification, and national highway system (NHS) categories.

Application in this Study: This information will be merged into the county characteristic database. The centerline miles, lane miles, daily VMT, and daily truck vehicle mileage of travel along with county population will be used to produce hotelling growth factors.

C.2 TCEQ Permits and Registration System

Description: Petroleum storage tanks (PSTs) statewide permit information can be retrieved from TCEQ's Permit and Registration Information System. This includes the owner and tank information and the latest amendment of the permit. The Permit and Registration Information System is a means for owners and the public to view the status of the permits in their city, county, and state. This information system can be queried by county and zip code for all 254 counties in Texas. Figure 38 shows a screen shot of sample registry information.

Central Registry Query - PST Certificate List

Facility Number	Facility Name	Address	Registration/COD
129	AUSTIN BAKING	5800 AIRPORT BLVD, AUSTIN , TX, 78752	No Document exists
2751	TEXAS DEPT OF PUBLIC SAFETY	5805 N LAMAR BLVD, AUSTIN , TX, 78752	View Registration View Certificate of Delivery
3641	MUCHOS GROCERY	7509 N IH 35, AUSTIN , TX, 78752	View Certificate of Delivery
3881	HENNA CHEVROLET	7522 N IH 35, AUSTIN , TX, 78752	No Document exists
4263	WOODS HONDA	6509 N LAMAR BLVD, AUSTIN , TX, 78752	No Document exists
7170	7-ELEVEN 12683	808 W KOENIG LN, AUSTIN , TX, 78752	No Document exists
7813	SEARS ROEBUCK & CO. 8337	108 DENSON DR, AUSTIN , TX, 78752	No Document exists
10806	TEXAS DEPT OF PUBLIC SAFETY	5900 GUADALUPE ST, AUSTIN , TX, 78752	No Document exists
11311	LAMAR CORNER STORE	7545 N LAMAR BLVD, AUSTIN , TX, 78752	View Registration View Certificate of Delivery
11333	SUPER K GRO	6700 GUADALUPE ST STE A, AUSTIN , TX, 78752	No Document exists
14748	BRIGHT TRUCK LEASING	911 E SAINT JOHNS AVE, AUSTIN , TX, 78752	No Document exists
14915	DISCOVER FOOD MART 1	7200 N IH 35, AUSTIN , TX, 78752	View Registration View Certificate of Delivery
15519	CONTINENTAL CARS	200 W HUNTLAND DR, AUSTIN , TX, 78752	No Document exists
17727	7-ELEVEN STORE 36618	7114 N IH 35, AUSTIN , TX, 78752	View Registration View Certificate of Delivery
18930	PAYLESS GAS 866	6608 N LAMAR BLVD, AUSTIN , TX, 78752	No Document exists
19074	FAMOUS FOOD MART	6301 N LAMAR BLVD, AUSTIN , TX, 78752	View Certificate of Delivery
19602	TEXAN MKT 4	7200 CAMERON RD, AUSTIN , TX, 78752	No Document exists

Figure 38. Sample TCEQ Registration Database of Underground Storage Petroleum Tanks.

Source: TCEQ.

Measured Variables: Permits issued on PSTs.

Temporal Coverage: Existing status of the facilities.

Spatial Coverage: Includes all 254 counties in Texas.

Application in this Study: This information will be used to verify the status of the truck stops with fueling facilities and underground storage tanks, which should be registered for an operating permit with TCEQ.

C.3 PREVIOUS STUDIES IN TEXAS

Description: Various data sets are available from prior studies, such as TTI (June 2003), ERG (ERG, Cambridge Systematics Inc., and Alliance Transportation Group, Inc., August 31, 2004), AACOG (October 31, 2011), CAPCOG (December 2013), which were conducted in Texas. Brief descriptions of each study are provided in the following.

TTI Study (2003) - Developed a study design for quantifying truck idling emissions in Texas and produced initial estimates of the magnitude of truck idling emissions in Texas.

ERG Study (2004) - Developed a statewide on-road HDV extended idling activity database and emissions inventory for all counties in Texas. The source generator categories considered included:

- Truck Stops and Travel Plazas;
- State-maintained Rest Areas and Travel Centers;
- Commercial Marine Ports;
- Airports; and
- Intermodal Rail Yards.

AACOG (2011) - Conducted a visual survey of engine idling practices by long-haul truck drivers at: truck stops, rest stops, and picnic areas.

CAPCOG (2013) - Developed a regional inventory of extended idling parking spaces for 2006, 2008, and 2012 along with estimates of idling activity and associated emissions.

Source: TCEQ, CAPCOG, AACOG.

Measured Variables: Idling location, parking spaces, occupancy rates, idling rates, idling variation by hour, electrification system, amenities.

Temporal Coverage:

- TTI Study –Thursday, July 10 and Friday, July 11, 2003.

- ERG Study - June 28, 2004 and ending August 27, 2004.
- AACOG Study – The number of surveys conducted per month included:
    - November 2010 - 9 surveys;
    - March 2011 - 48 surveys;
    - April 2011 - 38 surveys;
    - May 2011 - 61 surveys; and
    - June 2011 - 59 surveys.
- CAPCOG Study – July 2011 through October 2011.

Spatial Coverage:

- TTI Study – Beaumont Port Arthur Area
- ERG Study –
    - Daytime data collection:

        Week 1: Texarkana, Tyler/Longview, Laredo, McAllen, Corpus Christi, Victoria, Killeen/Temple, Lubbock, and Amarillo;

        Week 2: San Antonio, Dallas/Fort Worth, and Wichita Falls;

        Week 3: El Paso, San Angelo, Odessa/Midland, Abilene, and Houston; and

        Week 4: Houston.
    - 24-Hour Data Collection:

        Week 6: Houston and Dallas.
    - Nighttime data collection:

        Week 7: Abilene, Lubbock, and Amarillo;

        Week 8: Midland/Odessa, Laredo, Texarkana, Austin, and Tyler/Longview; and

        Week 9: San Antonio and Beaumont/Port Arthur.
- AACOG Study – San Antonio-New Braunfels Metropolitan Statistical Area (MSA) (Atascosa, Bandera, Comal, Guadalupe, Kendall, Medina, and Wilson)
- CAPCOG Study – Austin Area (Bastrop, Caldwell, Fayette, Hays, Travis, and Williamson counties):
    - Initial site visits to 16 potential truck idling locations in Bastrop, Caldwell, Fayette, Hays, Travis, and Williamson counties;
    - 176 observations at 7 truck stops in Caldwell, Hays, Travis, and Williamson counties;
    - 10 observations along interstate frontage roads in Hays, Travis, and Williamson counties;

- o 14 observations at Wal-Marts in Hays, Travis, and Williamson counties; and
- o 118 interviews with truck drivers.

Application in this Study: TTI will assemble, review, and evaluate the information from these studies. A database from these studies with information such as facility location, parking spaces, amenities, occupancy and idling percentage, and time-of-day variation will be developed. This information will used for validation and developing facility type idling rates for this study.

C.4 American Transportation Research Institute (ATRI)

Description: ATRI, part of the American Trucking Association (ATA) Federation, is a 501(c) (3) not-for-profit research organization headquartered in Arlington, TX. ATRI collects GPS-based, spatial, and temporal information for a large sample of trucks with onboard, wireless communication systems in the U.S. This data is used by planning agencies to improve freight planning and safety. Figure 39 and Figure 40 show the sample ATRI data coverage in the Dallas/Ft. Worth (DFW) area.

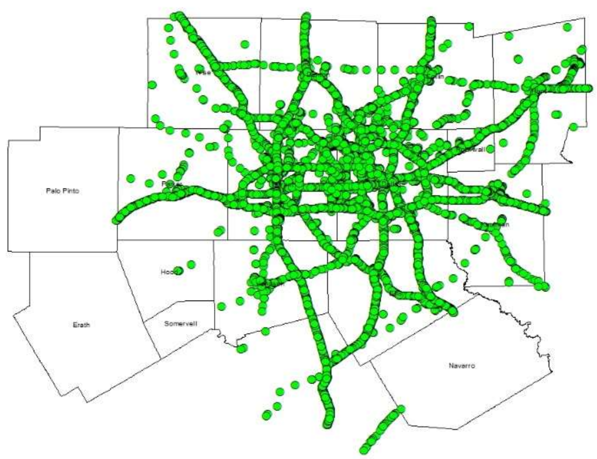


Figure 39. ATRI Data Coverage in the DFW Area.

Figure 40. ATRI Data Overlaid on a Truck Stop near an I-35 Corridor.

Source: ATRI.

Measured Variables: This data includes geospatial (coordinates) and temporal (time/date stamp) information for the corresponding trucks. Currently, more than 100 million GPS data points are collected per day by ATRI.

Temporal Coverage: 2002 to Present. For this study, TTI will use 2015 and 2016 data for every two weeks for four seasons for the year.

Spatial Coverage: The ATA represents over 35,000 motor carriers through the affiliated trucking associations in 50 states. This data is available for all 50 states of the U.S. For this study, TTI will acquire and process DFW and El Paso area data.

Application in this Study: Acquired data will be verified and processed to identify how many hours and where trucks were stopped by superimposing hotelling facility GIS layer files. Since the data are available at a fine temporal resolution, the data will also be used to identify the hourly parking rate at hotelling facilities.

C.5 INRIX

Description: INRIX collects real-time anonymous mobile phones, connected cars, trucks, delivery vans, and other fleet vehicles equipped with GPS locator devices. Data is provided as raw data, processed data, and/or as shape files. Roadway location is referenced to the traffic management canter (TMC). Data are processed to provide travel time, time-cost delays, trends maps and charts, bottleneck and incident data, and can provide the underlying anonymized historical data for download. The data collected is processed in real-time 24 hours a day, creating traffic speed information for major freeways, highways, and arterials across North America.

Source: Privately owned.

Measured Variables: Volume, speed and trips (origin-destination).

Temporal Coverage: 2002 to present in 1-, 5-, 15-, 30-, and 60-minute temporal resolutions. Every 15 minutes for 2015 and 2016.

Spatial Coverage: The data is available for all 50 states in the U.S. TTI will acquire data for metropolitan areas such as Austin, El Paso, DFW, San Antonio, and Houston for this study.

Application in this Study: This information will be used to analyze the travel characteristics on the access roadways for hotelling facilities.

C.6 National Performance Management Research Data Set (NPMRDS)

Description: The NPMRDS includes passenger vehicle probe data from mobile phones, vehicles, and portable navigation devices, and from freight probe data collected by ATRI and provided by HERE (a Geographic Positioning System provider). The NPMRDS consists of average travel times reported every five minutes on the NHS as defined in MAP-21[5] and on a five-mile radius of arterials at border crossings. It is monthly archived data. While the data is primarily for FHWA's use, FHWA is making the data available to states and MPOs, as well as to the Canadian and Mexican national governments, border provinces, and states to use for performance measures and to help grow the use and application of performance measures more locally and consistently. The NPMRDS data set includes a static file, a monthly data file, and a shape file of the NHS. Agency partners are encouraged to use the data set to develop systems performance measures for use in evaluating projects and operational strategies, as input

[5] Moving Ahead for Progress in the 21st Century Act (MAP-21) authorizes funds for federal-aid highways, highway safety programs, transit programs, and for other purposes and expands the NHS to incorporate principal arterials not previously included (source: https://www.fhwa.dot.gov/map21/summaryinfo.cfm.

into investment decision making, as calibration for models, and for producing publicly available reports. Figure 41 shows the NPMRDS roadway system.

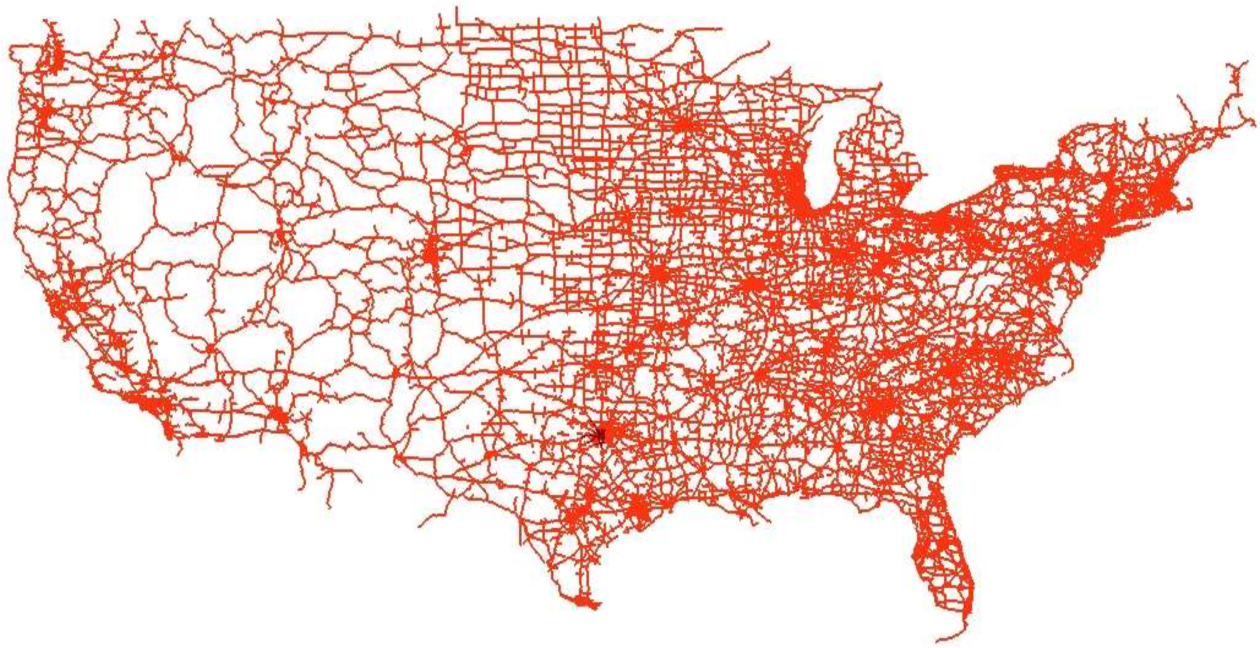


Figure 41. NPMRDS Roadway System.

Source: FHWA, https://ops.fhwa.dot.gov/perf_measurement/.

Measured Variables: Travel time for all vehicles (seconds), travel time for passenger vehicles (seconds), and travel time for freight vehicles (seconds), passenger, and truck ADT.

Temporal Coverage: The data are available from 2011 to present in 5-minute intervals.

Spatial Coverage: The data is available for all 50 states in the U.S.

Application in this Study: This information will be used to analyze the travel characteristics on the access roadways of hoteling facilities.

C.7 Rest Areas in Texas

Description: TxDOT builds and maintains rest stops along the major freight corridors in the state. These facilities help drivers fight driving-related fatigue and also provide other amenities such as modern restrooms, interpretive displays, exhibits of local features, separate parking for cars and trucks, and wireless internet access to entice travelers to stop and rest. Figure 42 shows all the active and closed rest areas and travel information centers in Texas.

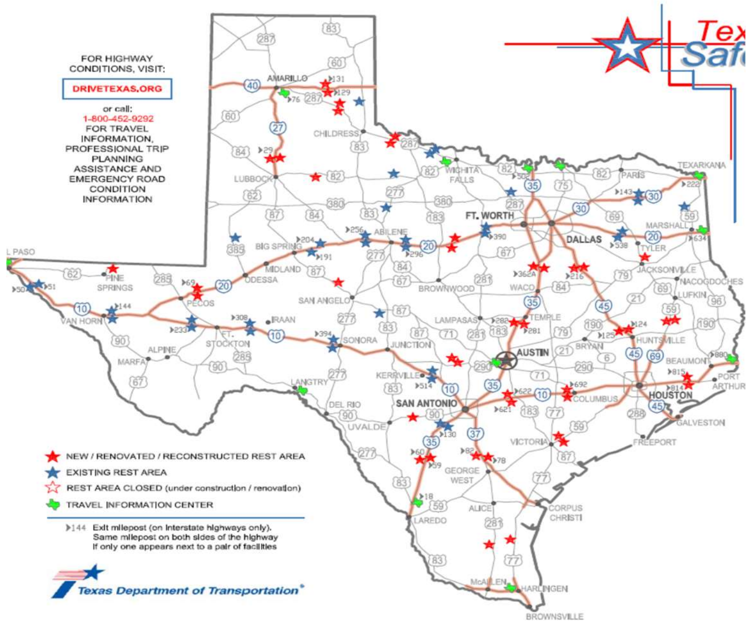


Figure 42. Location of Rest Areas in Texas.

Source: TxDOT.

Measured Variables: Name, address, and geographic location.

Temporal Coverage: Status of rest areas as of 2017.

Spatial Coverage: State of Texas.

Application in this Study: This data will be verified and processed to develop a database and spatial GIS layer with information such as address, county, parking spaces, etc. This information will be used in development of the hotelling facilities master list.

C.8 Truck Stop Locations

Description: There is no single source that can provide all the active truck stops available for Texas. There are multiple web sources that can provide truck-parking facilities in Texas. Figure 43 shows geocoded sample truck stops in Texas.

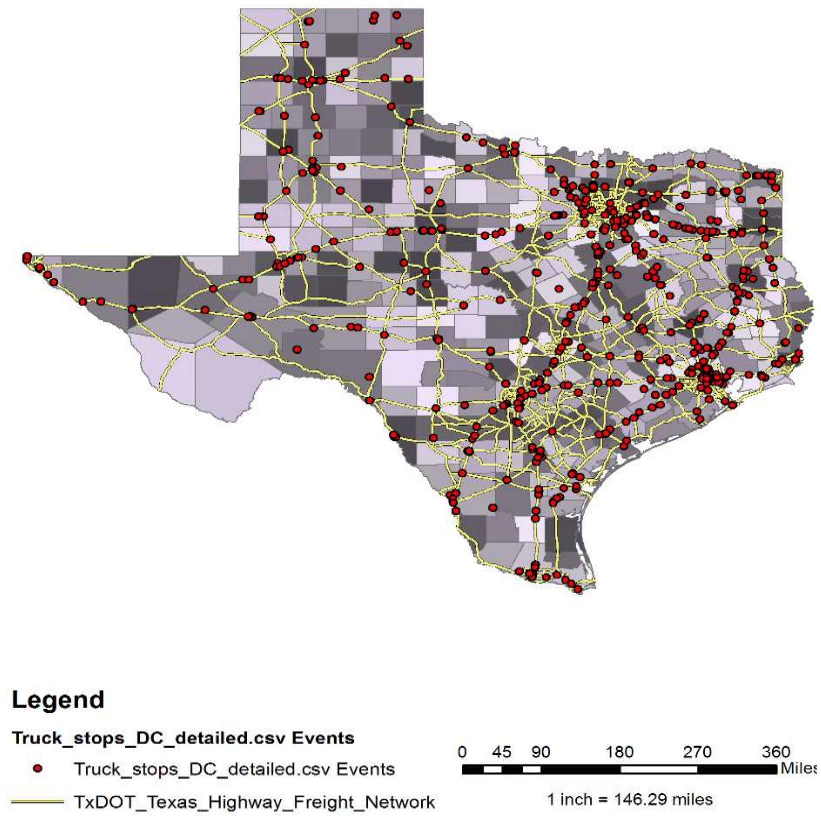


Figure 43. A Sample of Geocoded Locations of Truck Stops in Texas.

Source:

- truckstopsandservices.com.
- yellowpages.com.
- natsn.com.
- otrprotrucker.com.
- roadstaronline.com.
- trucker.com.
- truckerslink.com.

Measured Variables: Name, address, and geographic location, spaces, type of facility, parking, and driver amenities.

Temporal Coverage: Truck stops as of 2017.

Spatial Coverage: The data is available for all 50 states in the U.S.

Application in this Study: This data will be verified and processed to develop a database and spatial GIS layer with information such as address, county, parking spaces. This information will be used in developing the hotelling facilities master list.

C.9 DFW PARKING STUDY

Description: NCTCOG conducted a parking study in 2016 for the 16-county MPO boundary area. As part of this study, NCTCOG collected all information about truck parking facilities and whether overnight parking was available at these facilities. NCTCOG planned to use the information from this study for freight planning and safety improvements. Figure 44 shows geocoded truck parking locations in the DFW area.

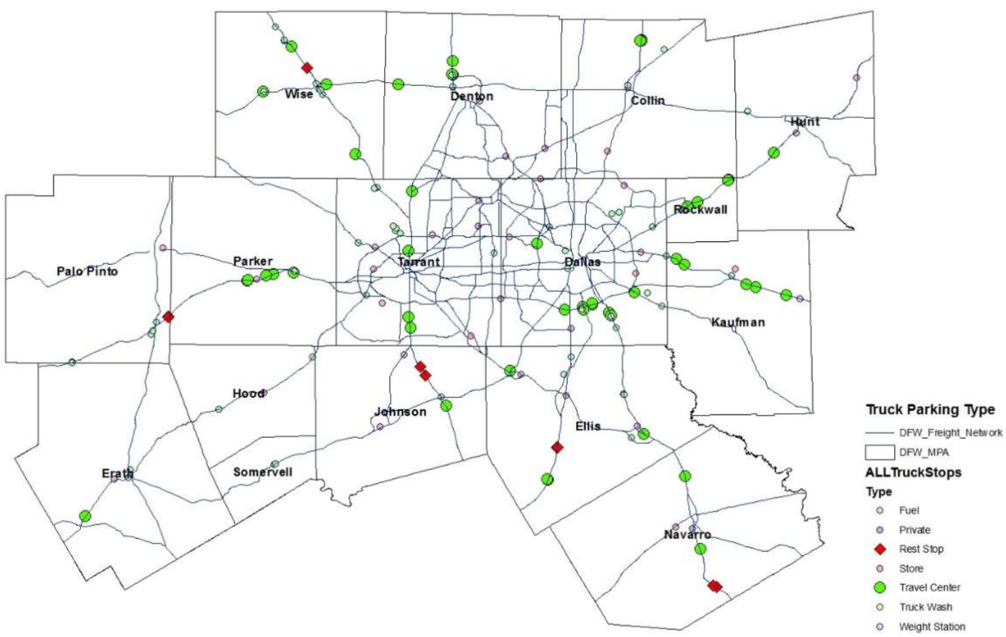


Figure 44. Truck Parking Locations in the DFW Area.

Source: NCTCOG.

Measured Variables: Name, address, geographic location, parking spaces, type of facility, overnight parking, driver amenities, and emissions control technology availability.

Temporal Coverage: Status as of 2016.

Spatial Coverage: 16 counties in north central Texas.

Application in this Study: This data will be verified and processed to develop a database and spatial GIS layer with information such as address, county, and parking spaces. This information will be used in developing the hotelling facilities master list.

C.10 TxDOT Vehicle Detection Units

Description: Vehicle detection units are installed on local highways and are used to measure traffic speeds and traffic volumes. Information from the vehicle detection units is transmitted to TxDOT districts, alerting staff to any changes in traffic operating speeds. Changes in traffic operating speeds allow staff to determine the locations of any potential incidents that may restrict traffic flow. These units are mounted alongside highways and are typically spaced one mile apart. Figure 45 shows locations of the Daltrans detectors. Each detector records volume, speed, and occupancy by lane and at 20-second intervals.

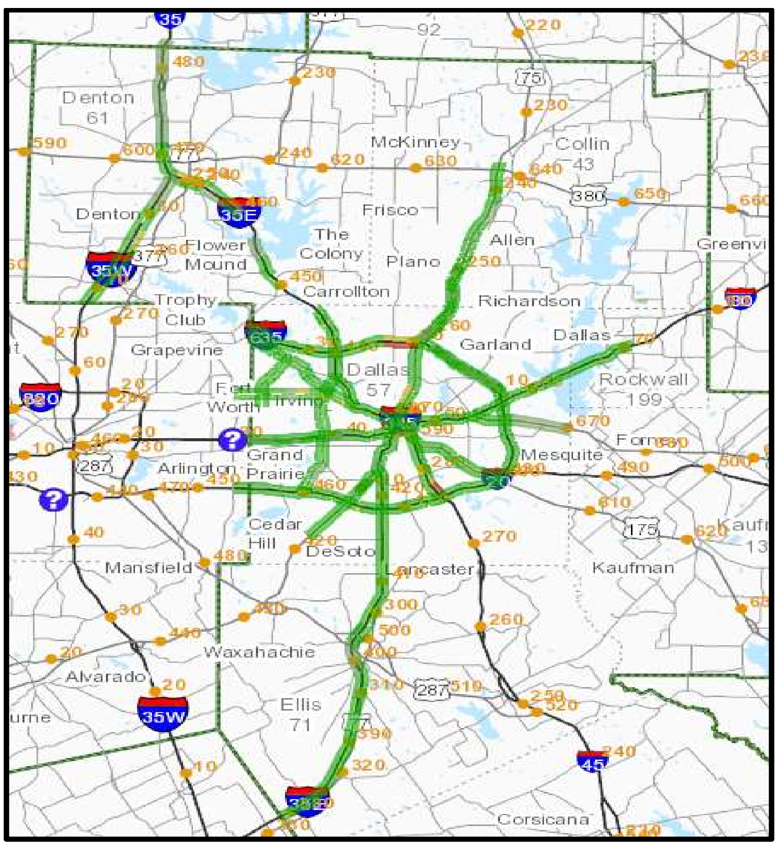


Figure 45. Daltrans Vehicle Detector Links.

Source: TxDOT.

Measured Variables: Volume, speed, by lane.

Temporal Coverage: 2015 to current date.

Spatial Coverage: Dallas, Ft. Worth, Houston, Austin, San Antonio, etc.

Application in this Study: Acquired data will be verified and processed to develop a database and spatial GIS layer with information including volume and speed on the freeway system. This information will be used to analyze the travel characteristics on the access roadways of hotelling facilities.

C.11 Google Data

Description: Google Maps/Google Earth allow you to view and use a variety of content, including map and terrain data, imagery, business listings, traffic, reviews, and other related information provided by Google, its licensors, and users. Figure 46 and Figure 47 show sample google imagery from 1995 and 2017 respectively.

Figure 46. Google Imagery from 1995 Showing the I-35 Corridor in Ft. Worth.

Figure 47. Google Imagery from 2017 Showing the I-35 Corridor in Ft. Worth.

Source: Google Inc.

Measured Variables: Map, terrain data, imagery, business listings, traffic, reviews, and other related information.

Temporal Coverage: Google Maps/Google Earth has historical imagery information (1990 to current). Google traffic is current information. It does not support viewing or accessing historical traffic data.

Spatial Coverage: The data is available for all 50 states in the U.S.

Other Notes: The Google Maps Directions API allows public users to query the database at any interval (seconds, minutes). The returned results contains the time it will take to travel between two points at a particular time and this data can be stored locally in the database.

Application in this Study: This information will be used to verify the status of the truck stops for various analysis years. The number of parking spaces will also be verified using this information.

C.12 TxDOT STARS-II

Description: TxDOT's STARS-II comprises a statewide database of traffic activity and a web-based GIS interface that can be used to search for and download traffic count data. STARS-II addresses the federal requirement that all states implement a traffic monitoring system (TMS) for highways and transportation facilities and equipment (23

CFR 500 part B) and the mandate that states must report comprehensive and standardized traffic information to the HPMS. The STARS-II data covers on- and off-system roadways within Texas. Traffic data are collected at approximately 362 permanent count locations using pneumatic tube traffic counters at the 362 permanent monitoring locations, plus many short-term locations that are strategically distributed across the state. Temporary locations are used within a dynamic sampling plan that covers approximately 75,000-to-80,000 locations annually. Urban areas are monitored on a five-year rotating cycle using saturation counts. Figure 48 shows a screen shot of the TxDOT STARS-II database.

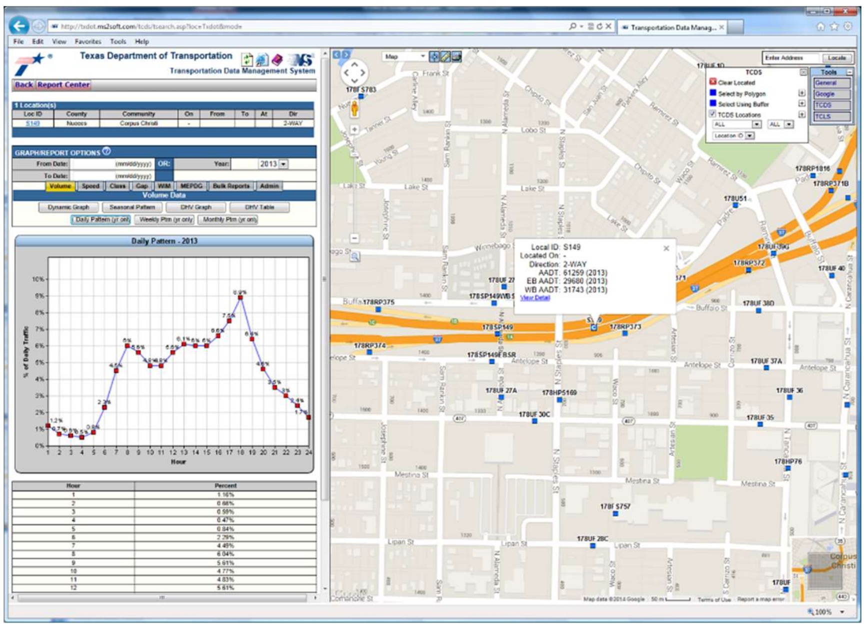


Figure 48. TxDOT STARS II Screen Shot.

Source: TxDOT.

Measured Variables: Traffic volumes, traffic volumes classified by vehicle type, vehicle speed, and vehicle weight.

Temporal Coverage: 1996 to current.

Spatial Coverage: Includes all 254 counties in Texas.

Application in this Study: This information will be used to analyze the travel characteristics on the access roadways for hotelling facilities.

C.13 TXDOT ROADWAY/HIGHWAY INVENTORY NETWORK

Description: The Roadway/Highway Inventory Network (RHiNO) data set is maintained and routinely updated by TxDOT to support planning and other functions. The RHiNO data set is a part of the Texas Reference Marker System (TRM) that was implemented in 1995. TxDOT is currently in the process of replacing the TRM legacy data system with a more advanced data system known as Geospatial Roadway Information Database (GRID). Currently, the RHiNO data set includes some 96,000 state highway records that cover 137 attributes and represents a wide range of items. Examples include reference marker displacement, highway status and type, functional class, maintenance responsibility, average annual daily traffic (AADT) for the previous 10 years, truck percentage, urban/rural status, shoulder width, median width, right-of-way width, roadbed width, posted speed limit, surface type and characteristics, and load limits. Originally, RHiNO data only included information for on-system roadways. TxDOT has gradually started including local roadways (i.e., city and county roads) in recent versions of RHiNO data. TxDOT's latest RHiNO data has included a relatively comprehensive coverage of the city and county roads across the state. Figure 49 shows the RHiNO data coverage in Texas.

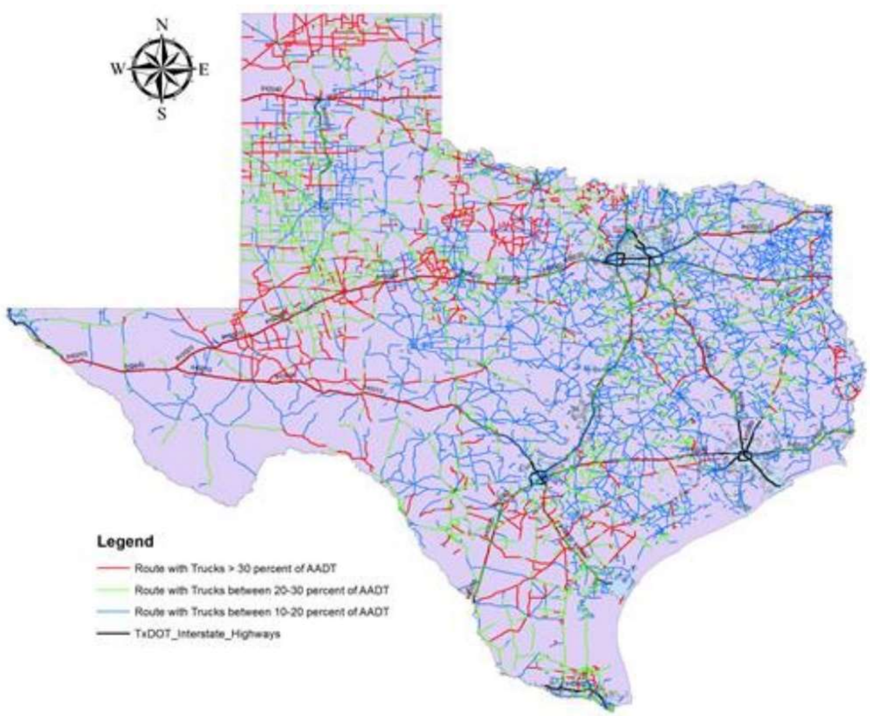


Figure 49. TxDOT RHiNO Data Coverage.

Source: TxDOT.

Measured Variables: Traffic volume.

Temporal Coverage: 1996 to current.

Spatial Coverage: Includes all 254 counties in Texas.

Application in this Study: This information will be used to analyze the travel characteristics on the access roadways of hotelling facilities.

C.14 Freight Analysis Framework (FAF)

Description: The FAF, produced through a partnership between the Bureau of Transportation Statistics (BTS) and the FHWA, integrates data from a variety of sources to create a comprehensive picture of freight movement among states and major metropolitan areas by all modes of transportation. The FAF is a compilation of data and products that provides estimates of freight shipped to (imports), from (exports), and within (domestic) the U.S. Figure 50 shows the roadway structure available from the FAF data source.

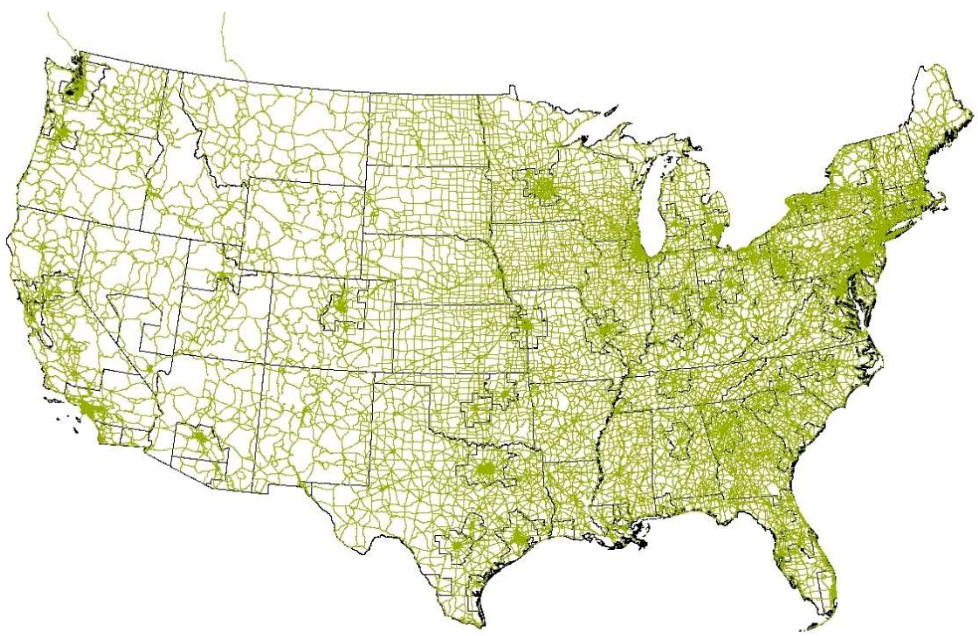


Figure 50. FAF Roadway Network and Zone Structure.

Source: FHWA.

Measured Variables: Commodity flow, all AADT, truck AADT.

Temporal Coverage: 2012 to 2045.

Spatial Coverage: The data is available for all 50 states in the U.S.

Other Notes: The FAF does not provide local detail or temporal (seasonal, daily, or hourly) variation in freight flows.

Application in this Study: This data will be verified and processed to estimate potential flow of commodities to each zone in Texas. Furthermore the AADT, truck AADT, etc., on each roadway in Texas will be clipped at the county level and summarized to be used in the county database.

C.15 Regional Integrated Transportation Information System (RITIS)

Description: The RITIS information system allows users with appropriate credentials to view all of the real-time RITIS data in a browser. The website provides users with a dynamic set of visualizations and tools that afford efficient situational awareness. Authorized users can interact with live events, incidents, weather, sensors, radio scanners, response vehicles, and other data sources and devices in maps, lists, and other graphics.

There are three main RITIS components including:

1. Real-time data feeds;
2. Real-time situational awareness tools; and
3. Archived data analysis tools.

A number of online tools have been developed to allow users to query, analyze, and derive performance measures from the RITIS archive. Many of these tools are highly interactive and dynamic. Figure 51 shows an example of speed variation on the facilities in the Austin area developed using the RITIS tools. Figure 52 shows incident events in the DFW area developed using the RITIS tools. Data within the archive can also be ***downloaded and/or exported*** so that users can perform their own, independent analysis.

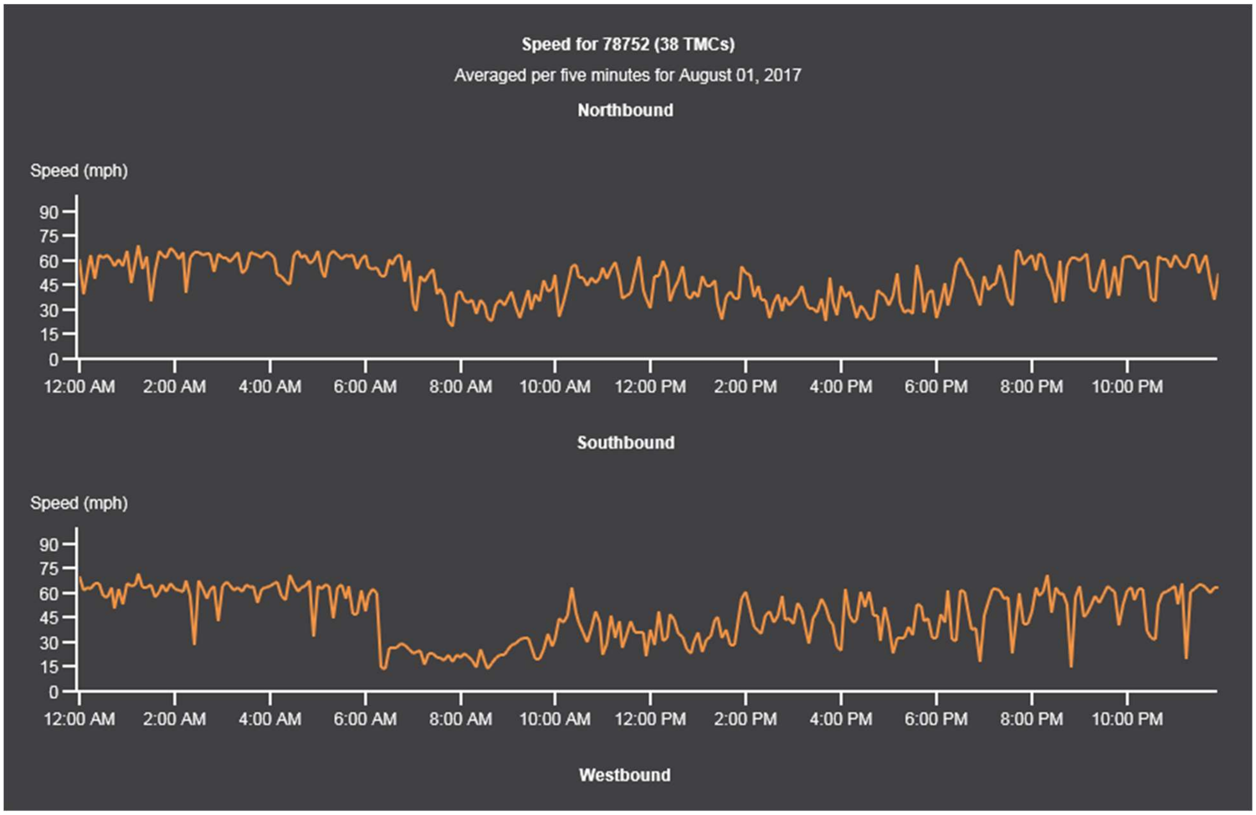


Figure 51. RITIS Tools for Analyzing NPMRDS Data in the Austin Area.

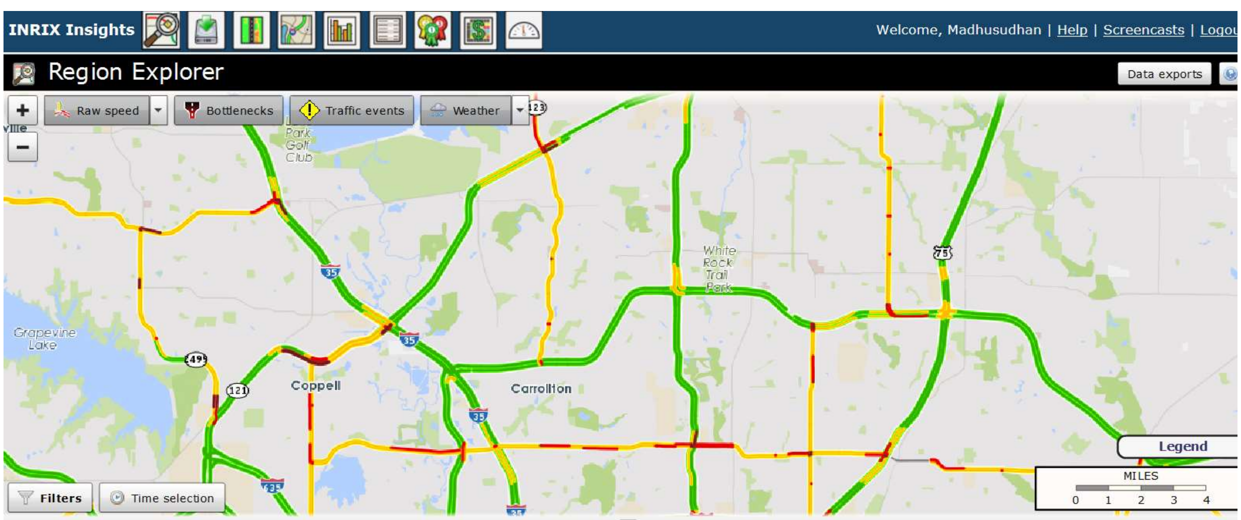


Figure 52. RITIS Regional Explorer Tool using INRIX Data.

Source: RITIS, University of Maryland.

Measured Variables: Vehicle probe data from INRIX, NPMRDS.

Spatial Coverage: The data is available for all 50 states in the U.S.

Application in this Study: This information will be used to analyze the travel characteristics on the access roadways of hotelling facilities.

C.16 Other GIS Data Sets

Description: Various other spatial data sets that are available to TTI staff for this study include:

- U.S. Census 2010;
- TxDOT highway designations;
- Texas highway freight network;
- Texas national highway freight network;
- Texas railroads;
- Texas airport boundaries;
- TxDOT roadway inventory;
- TxDOT functional classification; and
- Texas MPOs.

Source: TxDOT and Texas Natural Resources Information System.

Measured Variables: Population and transportation characteristics.

Spatial Coverage: The data is available for all 50 states in the U.S.

Application in this Study: This data will be verified and processed to develop a database and spatial GIS layer with population, projected AADT, rail ports, etc. This information will be used in developing hotelling facilities and county information master lists.

APPENDIX D. NUMBER OF IDLING LOCATIONS BY COUNTY

COUNTY	PICNIC AREA	REST AREAS	TRAVEL CENTER	TRUCK STOP	WALMART	GRAND TOTAL
HARRIS				72	9	81
BEXAR				21	6	27
DALLAS				20	6	26
PECOS	7	4		7	1	19
EL PASO	4	2	1	10	2	19
MCLENNAN				16	1	17
CULBERSON	8	3		5		16
WISE	1	1		13		15
TARRANT				11	3	14
SMITH	3			10	1	14
HIDALGO				13		13
WEBB	3		1	9		13
LUBBOCK	2			10		12
TRAVIS	1			4	7	12
MIDLAND	2			9	1	12
WILLIAMSON				5	6	11
BOWIE			1	9	1	11
KIMBLE	4			7		11
POLK	2	2		6		10
PARKER	2			7	1	10
NACOGDOCHES	3			7		10
HILL	1	2		6	1	10
EASTLAND	3	2		5		10
ELLIS				9	1	10
POTTER	2		1	7		10
LIVE OAK		2		8		10
FAYETTE	4			5	1	10
MONTGOMERY				9		9
COLORADO	2	2		4	1	9
CHAMBERS		2		7		9
FRIO				9		9
SAN PATRICIO	3			6		9
LEON	4			5		9
BELL	1	2		5		8
HUNT	1			6	1	8
WALLER				8		8

COUNTY	PICNIC AREA	REST AREAS	TRAVEL CENTER	TRUCK STOP	WALMART	GRAND TOTAL
WICHITA		2		5	1	8
LA SALLE		2		6		8
MILAM	5			3		8
VICTORIA		2		5		7
FORT BEND				7		7
BASTROP				6	1	7
NOLAN	1	2		4		7
VAL VERDE	6			1		7
OLDHAM	5			2		7
GALVESTON	3			3	1	7
PALO PINTO	3			4		7
SUTTON	4	2		1		7
HOWARD	4	1		2		7
ERATH	7					7
GUADALUPE		2		5		7
VAN ZANDT		2		5		7
MAVERICK	3			4		7
COMAL	3			4		7
ATASCOSA	4			3		7
NAVARRO	2	2		3		7
DENTON				7		7
KAUFMAN				7		7
ECTOR				6		6
TAYLOR				6		6
HOPKINS	2	2		2		6
BRAZORIA	3			3		6
HAYS	1			3	2	6
BROWN	4			2		6
WHARTON				6		6
CROCKETT	5			1		6
ANDREWS	3	1		2		6
FREESTONE	1			5		6
CHEROKEE	3			3		6
CALLAHAN	2	2		2		6
WALKER		2		4		6
RANDALL	4			1	1	6
WARD	1	2		3		6
REEVES	3			3		6
WILBARGER	4			2		6
GAINES	3			3		6

COUNTY	PICNIC AREA	REST AREAS	TRAVEL CENTER	TRUCK STOP	WALMART	GRAND TOTAL
CAMERON			1	5		6
GREGG				5		5
KENDALL	2			2	1	5
NUECES				4	1	5
HAMILTON	3			2		5
AUSTIN	1			3	1	5
JASPER	2			3		5
MONTAGUE	3			2		5
MEDINA	1	3		1		5
COLLIN				4	1	5
SHELBY	3			2		5
TOM GREEN	1			4		5
SHERMAN	3			2		5
JOHNSON				5		5
FRANKLIN		2		2		4
BURLESON	3			1		4
RUSK	3			1		4
HARRISON	1		1	2		4
BREWSTER	4					4
CLAY	3			1		4
WHEELER	2			2		4
MOORE	2			2		4
SCURRY	2			2		4
KLEBERG				4		4
HUDSPETH	3			1		4
ANGELINA				4		4
HALE	1	2		1		4
CARSON	3			1		4
CORYELL	3			1		4
GARZA	3			1		4
ROCKWALL				4		4
LIMESTONE	2			2		4
MITCHELL	2	1		1		4
ORANGE			1	3		4
HOUSTON	2			2		4
JIM WELLS				4		4
CROSBY		1		2		3
CONCHO	2	1				3
BRAZOS				3		3
DEAF SMITH				3		3

COUNTY	PICNIC AREA	REST AREAS	TRAVEL CENTER	TRUCK STOP	WALMART	GRAND TOTAL
BROOKS		1		2		3
JONES	3					3
ZAVALA	2			1		3
CALDWELL				2	1	3
ARMSTRONG	2			1		3
KERR	1	2				3
HASKELL	1	1		1		3
DIMMIT	2			1		3
HOCKLEY	3					3
DONLEY		3				3
DALLAM	1			2		3
LAMB	2			1		3
PARMER	1			2		3
LEE				2	1	3
ROBERTSON	1			2		3
LIBERTY	1			2		3
HARDEMAN		2		1		3
LIPSCOMB	1			2		3
STERLING	2			1		3
MADISON				2	1	3
HEMPHILL	1			2		3
MORRIS				3		3
UVALDE	2			1		3
NEWTON	3					3
HOOD	1			2		3
OCHILTREE	1			2		3
WASHINGTON	1			2		3
GILLESPIE	3					3
JACK	3					3
GRAY		1		2		3
PANOLA				3		3
GRIMES	3					3
MCCULLOCH	1			1		2
TITUS				2		2
ARCHER	1			1		2
FOARD	2					2
UPTON	2					2
CHILDRESS				2		2
ZAPATA	2					2
BAILEY	2					2

COUNTY	PICNIC AREA	REST AREAS	TRAVEL CENTER	TRUCK STOP	WALMART	GRAND TOTAL
TERRELL	1			1		2
COKE		1		1		2
LYNN	2					2
DUVAL				2		2
BAYLOR				2		2
GRAYSON			1	1		2
JACKSON				2		2
JEFFERSON				2		2
STEPHENS	2					2
PRESIDIO	2					2
BLANCO				2		2
REAGAN	1			1		2
TERRY	1			1		2
RED RIVER	2					2
HENDERSON	2					2
HALL	1			1		2
TYLER	1			1		2
REFUGIO				2		2
CRANE	2					2
ROBERTS	2					2
CASS		1		1		2
ARANSAS	2					2
FANNIN	1			1		2
HARDIN				2		2
BURNET				1	1	2
KINNEY	2					2
SOMERVELL	2					2
SHACKELFORD	2					2
ANDERSON				1		1
KARNES	1					1
WILLACY				1		1
BORDEN	1					1
COTTLE	1					1
SAN SABA	1					1
CALHOUN	1					1
KENEDY		1				1
HANSFORD	1					1
MENARD	1					1
MILLS	1					1
COMANCHE	1					1

COUNTY	PICNIC AREA	REST AREAS	TRAVEL CENTER	TRUCK STOP	WALMART	GRAND TOTAL
MATAGORDA				1		1
GONZALES				1		1
COLEMAN	1					1
HARTLEY	1					1
MCMULLEN				1		1
LAMPASAS				1		1
JEFF DAVIS	1					1
STARR				1		1
SAN AUGUSTINE				1		1
LAREDO	1					1
UPSHUR				1		1
BOSQUE	1					1
DELTA	1					1
STONEWALL	1					1
MARTIN				1		1
LOVING	1					1
COCHRAN	1					1
SWISHER				1		1
FISHER	1					1
BRISCOE	1					1
BEE	1					1
LAVACA	1					1
IRION	1					1
BANDERA	1					1
DEWITT	1					1
FLOYD	1					1
RUNNELS				1		1
THROCKMORTON	1					1
WOOD	1					1
COLLINGSWORTH		1				1
CASTRO	1					1
KNOX		1				1
RAINS				1		1
GRAND TOTAL	**330**	**75**	**9**	**700**	**64**	**1178**

APPENDIX E. THERMAL SURVEY INFORMATION LETTERS

Texas Transportation Institute
Transportation Planning Program
The Texas A&M University System
3135 TAMU
College Station, TX 77843-3135

979-845-3326
Fax: 979-845-7548
http://tti.tamu.edu

November 27, 2017

To whom it may concern:

The Texas A&M Transportation Institute (TTI), a part of the Texas A&M University System, is performing a study of long-haul truck idling on behalf of the Texas Commission on Environmental Quality (TCEQ). The U.S. Environmental Protection Agency (EPA) bases estimates of local truck idle emissions on levels of truck traffic in a region, and not on the actual number of trucks found to idle at truck stops. The aim of this study is to help TCEQ collect field data to accurately estimate that the actual air pollution contribution of truck stops in different areas of the state.

Several truck stop facilities along IH-35 between Georgetown and Temple have been selected for the study which will be performed between Monday, November 27th and Wednesday, November 29th, 2017. The study will be conducted by a team of two researchers over a 3-day period. It will include periodic thermal camera surveys on the trucks parked on-site to identify the number of trucks idling. The thermal cameras record only heat footprints and do not record photographic images. No personal information about truck drivers or identifying information about specific trucks will be collected.

If you need further information or have any concerns with regards to this study please contact Dr. Reza Farzaneh, 512-467-0946, m-farzaneh@tamu.edu.

Thank you for your cooperation.

Sincerely

Reza Farzaneh
Air Quality Program
Texas A&M Transportation Institute

Transportation Planning Program

Texas A&M Transportation Institute
Air Quality Program
Texas A&M University System
3135 TAMU
College Station, Texas 77843-3135

979-845-3326
Fax: 979-845-7548
http://tti.tamu.edu

December 4, 2017

To whom it may concern:

The Texas A&M Transportation Institute (TTI), a part of the Texas A&M University System, is performing a study of long-haul truck idling on behalf of the Texas Commission on Environmental Quality (TCEQ). The U.S. Environmental Protection Agency (EPA) bases estimates of local truck idle emissions on levels of truck traffic in a region, and not on the actual number of trucks found to idle at truck stops. The aim of this study is to help TCEQ collect field data to accurately estimate that the actual air pollution contribution of truck stops in different areas of the state.

Several truck stop facilities along IH-35 between Hillsboro and Italy, Texas have been selected for the study which will be performed between Monday, December 4th through Wednesday, December 6th, 2017, weather permitting. The study will be conducted by a team of two researchers over a 3-day period. It will include periodic thermal camera surveys on the trucks parked on-site to identify the number of trucks idling. The thermal cameras record only heat footprints and do not record photographic images. No personal information about truck drivers or identifying information about specific trucks will be collected.

If you need further information or have any concerns with regards to this study please contact Dr. Reza Farzaneh, 512-467-0946, m-farzaneh@tamu.edu.

Thank you for your cooperation.

Sincerely

for

Reza Farzaneh
Air Quality Program
Texas A&M Transportation Institute

Environment and Air Quality Division

Texas A&M Transportation Institute
Air Quality Program
Texas A&M University System
3135 TAMU
College Station, Texas 77843-3135

979-845-3326
Fax: 979-845-7548
http://tti.tamu.edu

December 8, 2017

To whom it may concern:

The Texas A&M Transportation Institute (TTI), a part of the Texas A&M University System, is performing a study of long-haul truck idling on behalf of the Texas Commission on Environmental Quality (TCEQ). The U.S. Environmental Protection Agency (EPA) bases estimates of local truck idle emissions on levels of truck traffic in a region, and not on the actual number of trucks found to idle at truck stops. The aim of this study is to help TCEQ collect field data to accurately estimate that the actual air pollution contribution of truck stops in different areas of the state.

Several truck stop facilities along IH-10 from State Highway 330 to just east of State Highway 146 South in Baytown, Texas have been selected for the study which will be performed between Tuesday, December 11th through Thursday, December 14th, 2017, weather permitting. The study will be conducted by a team of two researchers over a 4-day period. It will include periodic thermal camera surveys on the trucks parked on-site to identify the number of trucks idling. The thermal cameras record only heat footprints and do not record photographic images. No personal information about truck drivers or identifying information about specific trucks will be collected.

If you need further information or have any concerns with regards to this study please contact Dr. Reza Farzaneh, 512-467-0946, m-farzaneh@tamu.edu.

Thank you for your cooperation.

Sincerely

for

Reza Farzaneh
Air Quality Program
Texas A&M Transportation Institute

Environment and Air Quality Division

Texas A&M Transportation Institute
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December 8, 2017

To whom it may concern:

The Texas A&M Transportation Institute (TTI), a part of the Texas A&M University System, is performing a study of long-haul truck idling on behalf of the Texas Commission on Environmental Quality (TCEQ). The U.S. Environmental Protection Agency (EPA) bases estimates of local truck idle emissions on levels of truck traffic in a region, and not on the actual number of trucks found to idle at truck stops. The aim of this study is to help TCEQ collect field data to accurately estimate that the actual air pollution contribution of truck stops in different areas of the state.

Several truck stop facilities along IH-10 from Loop 410 to FM 2538 (east of San Antonio, Texas) have been selected for the study which will be performed between Tuesday, December 12th through Thursday, December 14th, 2017, weather permitting. The study will be conducted by a team of two researchers over a 3-day period. It will include periodic thermal camera surveys on the trucks parked on-site to identify the number of trucks idling. The thermal cameras record only heat footprints and do not record photographic images. No personal information about truck drivers or identifying information about specific trucks will be collected.

If you need further information or have any concerns with regards to this study please contact Dr. Reza Farzaneh, 512-467-0946, m-farzaneh@tamu.edu.

Thank you for your cooperation.

Sincerely

for

Reza Farzaneh
Air Quality Program
Texas A&M Transportation Institute

Environment and Air Quality Division

APPENDIX F. APU SURVEY QUESTIONNAIRE

Auxiliary Power Unit (APU) Usage Survey

Survey Setting
Facility:
Location:
Date: Time: Day / Night Survey Team Member:
Tractor-Trailer APU Survey
1. Do you typically drive long-haul* or local routes? (*long-haul = over-night stays)
2. What is the age and model of the vehicle?
3. Is the vehicle yours or company owned?
4. Is the vehicle part of a fleet?
5. Do you have an idle reduction technology[1] onboard the vehicle, such as an APU, shore power adaptor, fuel-operated heater, etc.?
6. If so, specify the type technology (diesel, battery, shore power)
7. During a typical rest period, how many hours do you use idle reduction technology? Engine idling? No power?
8. How many rest stops do you make in a typical long-haul route?
9. For what purpose do you typically use engine idling or your APU?

No.	1. Semi?	2. Vehicle Age or Year?	3. Vehicle Owner?	4. In a Fleet?	5. Has IRT[1]?	6. IRT[1] Power?	7. Hours Used?	8. No. of Rest Stops	9. Reason for Power Need?
1	Long Haul Local		Driver Company	Yes No	Yes No	Diesel APU Battery APU Shore power ----------------------	Idle Reduction: Engine Idle: No Power:		A/C-Heat Lighting Entertainment ------------------
2	Long Haul Local		Driver Company	Yes No	Yes No	Diesel APU Battery APU Shore power ----------------------	Idle Reduction: Engine Idle: No Power:		A/C-Heat Lighting Entertainment ------------------
3	Long Haul Local		Driver Company	Yes No	Yes No	Diesel APU Battery APU Shore power ----------------------	Idle Reduction: Engine Idle: No Power:		A/C-Heat Lighting Entertainment ------------------
4	Long Haul Local		Driver Company	Yes No	Yes No	Diesel APU Battery APU Shore power ----------------------	Idle Reduction: Engine Idle: No Power:		A/C-Heat Lighting Entertainment ------------------
5	Long Haul Local		Driver Company	Yes No	Yes No	Diesel APU Battery APU Shore power ----------------------	Idle Reduction: Engine Idle: No Power:		A/C-Heat Lighting Entertainment ------------------

[1] Idle Reduction Technology (IRT) includes APUs, TSE adaptors, cab/bunk heaters, coolant heaters, energy recovery systems, storage A/C, auto engine start/stop.

TCEQ Heavy-Duty Vehicle Idle Activity Study, Task 3 – Activity Data Collection, 2017

APPENDIX G. QUESTIONNAIRE INFORMATION SHEET

Truck Drivers' Questionnaire	3135 TAMU, College Station Texas 77843-3135 (979) 845-1713	Texas A&M Transportation Institute

You have been asked to participate in a research study about truck idling activities in Texas. The purpose of this study is to gather information on the duration, extent, and other characteristics of idling and power sources used by long-haul trucks during rest or hoteling periods. You were selected to be a possible participant because you drive a long-haul truck. Texas A&M Transportation Institute (TTI) is conducting this study on behalf of the Texas Commission on Environmental Quality (TCEQ).

If you agree to participate in this study, you will be asked to answer a few questions regarding your vehicle and typical long-haul route rest periods. This study will take about five minutes.

Your participation is voluntary. This study is anonymous and **no personally identifying information will be collected**. You may decide not to participate or to withdraw at any time without your current or future relations with Texas A&M University, the Texas A&M Transportation Institute, or TCEQ being affected.

If you have questions regarding this study, you may contact the study supervisor, Dr. Reza Farzaneh, 512-467-0946, m-farzaneh@tamu.edu. Please be sure you have read the above information, asked questions and received answers to your satisfaction. More information is provided in the next page. If you would like to be in the study, please proceed to the information sheet (page 2) and the questionnaire (page 3).

Thank you for your consideration.

Texas A&M Transportation Institute
3135 TAMU
College Station
Texas 77843-3135
(979) 845-1713

Page 1 of 3

SURVEY INFORMATION

Determining Extended Idling Activities of Long-Haul Trucks in Texas

Introduction

The purpose of this form is to provide you (as a prospective research study participant) with information that may affect your decision as to whether or not to participate in this research.

You have been asked to participate in a research study about truck idling emissions. The purpose of this study is to gather information on the generation of idling emissions by long-haul heavy trucks in major metropolitan areas in Texas. You were selected to be a possible participant because you drive a long-haul truck. This study is being sponsored/funded by the Texas Commission on Environmental Quality (TCEQ).

What will I be asked to do?

If you agree to participate in this study, you will be asked to answer a few questions regarding your vehicle and typical long-haul route rest periods. This study will take about five minutes.

What are the risks involved in this study?

The risks associated with this study are minimal, and are not greater than risks ordinarily encountered in daily life.

What are the possible benefits of this study?

You will receive no direct benefit from participating in this study; however, the information you provide will be combined with other data collected and used to create new emissions models used for air quality research in the greater Austin area.

Do I have to participate?

No. Your participation is voluntary. You may decide not to participate or to withdraw at any time without your current or future relations with Texas A&M University, the Texas A&M Transportation Institute, or TCEQ being affected.

Will I be compensated?

Unfortunately, no. However, we greatly appreciate your help with this survey.

Who will know about my participation in this research study?

This study is anonymous and no personally identifying information will be collected.

Whom do I contact with questions about the research?

If you have questions regarding this study, you may contact Reza Farzaneh, 512-467-0946, r-farzaneh@tti.tamu.edu.

Whom do I contact about my rights as a research participant?

This research study has been reviewed by the Human Subjects' Protection Program and/or the Institutional Review Board at Texas A&M University. For research-related problems or questions regarding your rights as a research participant, you can contact these offices at 979-458-4067 or irb@tamu.edu.

Participation

Please be sure you have read the above information, asked questions and received answers to your satisfaction. If you would like to be in the study, please indicate so to the interviewer.

Page 2 of 3

Truck Drivers' Questionnaire

3135 TAMU, College Station
Texas 77843-3135
(979) 845-1713

Texas A&M Transportation Institute

Q1. Do you typically drive long-haul* or local routes? (*long-haul = over-night stays)

Q2. What is the make of the vehicle?

Q3. What is the age or model year of the vehicle?

Q4. Is the vehicle yours or company-owned?

Q5. Does the vehicle operate as part of a fleet?

Q6. Do you have an idle reduction technology[1] onboard the vehicle, such as an APU, shore power adaptor, fuel-operated heater, etc.?

Q7. If so, specify the type of technology (diesel, battery, shore power, etc.)

Q8. During a typical rest period, how many hours do you use idle reduction technology?
Engine idling?
Nothing?

Q9. How many rest stops do you make in a day on a typical long-haul route?

Q10. For what purpose do you typically use engine idling or your APU/idle-reduction technology?

[1] Idle Reduction Technology (IRT) includes APUs, TSE adaptors, cab/bunk heaters, coolant heaters, energy recovery systems, storage A/C, auto engine start/stop.

Page 3 of 3

APPENDIX H. ELECTRONIC DATA LIST

1. **2017Annual (folder)**
   2017 annual emissions as estimated for the 2017 AERR using the data collected for this study. Summaries and associated files are included.
2. **2017swkd_summaries (folder)**
   2017 summer weekday emissions as estimated for the 2017 AERR using the data collected for this study. Summaries and associated area specific files are included.

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